Joint Transportation Research Program

JTRP

FHWA/IN/JTRP-98/12

Final Report

ASSESSING AND UPDATING INDOT'S TRAFFIC MONITORING SYSTEM FOR HIGHWAYS

VOLUME I: MAIN REPORT

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September 1998

Indiana Department of Transportation

Purdue University

FINAL REPORT
(Volume 1: Main Report)

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Project No.: C-36-64K
File No.: 3-5-11, HPR-0438

Prepared in Cooperation with the
Indiana Department of Transportation and
The U.S. Department of Transportation
Federal Highway Administration

Purdue University
West Lafayette, Indiana 47907

September 30, 1998

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance provided by Don Houterloot, John Nagle, Henry Rhee, Mohammed Shaikh, all of INDOT Roadway Management Division. Thanks are also extended to other INDOT staff such as Steve Smith, Marcia Gustafson, Geraldine Lampley, Leah Snow and Cordelia Jones-Hill. Persons responsible for the development of the various management systems such as Robert Woods, John Weaver, and Kirk Mangold provided valuable information for this study.

The contributions of the Metropolitan Planning Organizations (MPOs) in the State of Indiana, as well as several states' DOTs, whose personnel responded to our questions and questionnaires, are gratefully acknowledged. Professor Kuczek of the Statistics Department of Purdue University also provided useful help regarding the statistical aspects of the study. The comments and contributions of Larry Heil, Lisa Gion, and Don Johnson of the FHWA were useful through out the course of this study.

Finally, we are grateful for the financial support and research opportunity provided by the Indiana Department of Transportation and Purdue University through the Joint Transportation Research Program (JTRP).

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/IN/JTRP-98/12		

4. Title and Subtitle	5. Report Date
Assessing and Updating INDOT's Traffic Monitoring System for Highways (2 Volumes)	September 1998
	6. Performing Organization Code
7. Author(s)	**8. Performing Organization Report No.**
S. Labi and J. Fricker	FHWA/IN/JTRP-98/12
9. Performing Organization Name and Address	**10. Work Unit No.**
Joint Transportation Research Program 1284 Civil Engineering Building Purdue University West Lafayette, Indiana 47907-1284	
	11. Contract or Grant No. HPR-0438
12. Sponsoring Agency Name and Address	**13. Type of Report and Period Covered**
Indiana Department of Transportation State Office Building 100 North Senate Avenue Indianapolis, IN 46204	Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the Indiana Department of Transportation and Federal Highway Administration.

16. Abstract

This study evaluates the existing resources and procedures of INDOT's current traffic monitoring program, with the objective of transforming this program into a comprehensive Traffic Monitoring System for Highways (TMS/H). Reliable traffic data is a valuable input for studies and decision-making at various levels and in various phases of highway management including planning and design, finance and taxation, legislation and safety. The nature and scope of the various components comprising a TMS/H for any state were identified in available literature such as the Federal Register and Traffic Monitoring Guide.

A complete inventory of the existing resources (personnel and equipment) and procedures used for field data collection and office-based data processing were compiled and evaluated for adequacy and/or accuracy and appropriateness by matching them with requirements stated in available literature to ensure compliance with ISTEA recommendations.

In general, the existing traffic monitoring program was found to be adequate in meeting the needs of most management systems, with the exception of vehicle classification monitoring at sections having 'abnormal' traffic conditions. For the Continuous Count program, a large number of additional classification ATR stations are recommended while very few additional WIM sites are needed. All HPMS sample sections and NHS segments are covered under the existing program, although a lack of resources sometimes limits the frequency of data collection. Also, a new schedule for coverage counts is proposed to place greater emphasis on NHS roads and high-growth areas of the state. A new database system is recommended to effectively address data management issues. Also, documentation of field operations and office factoring procedures was carried out in this study.

With the recommendations from this study, INDOT intends to streamline its overall data collection activities and to improve the accuracy, adequacy, timeliness, and delivery of data to the end-users.

17. Key Words	18. Distribution Statement
Traffic monitoring, management systems, highway performance monitoring system, continuous counts, coverage counts, national highway system, vehicle occupancy, database system, adjustment factors.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	542	

Form DOT F 1700.7 (8-69)

EXECUTIVE SUMMARY

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) established a new emphasis in transportation system policy in the United States. This legislation mandated, among other requirements, the development and implementation of a Traffic Monitoring System for Highways (TMS) in each state. The *Federal Register* of December 1993 defines a TMS as a systematic process for the collection, analysis, summary and retention of roadway related person and vehicular data, including public transportation on public highways and streets. This study did not establish an entirely new TMS for the State of Indiana, but rather involved validation of existing procedures and resources, and recommendations for improving INDOT's current traffic monitoring program to a traffic monitoring system. Cost estimates have been provided for all recommendations that have been made. With the recommendations from this study, INDOT intends to streamline its overall data collection activities and to improve the accuracy, adequacy and timeliness of data collection, processing and analysis. The main references used in this study were the *HPMS Field Manual*, FHWA's *Traffic Monitoring Guide*, the *AASHTO Guidelines for Traffic Data Programs*, and Subpart H (Traffic Monitoring System for Highways) of the *Federal Register* dated 1 December 1993. Based on the components of a TMS required by ISTEA, the following areas were addressed:

The Management Systems- Generally, the existing traffic monitoring system is adequate to meet the needs of most management systems. The only significant shortcoming that needs to be addressed is monitoring of vehicle classification at high-speed, low-speed, and congested sections. For this, the use of "non-intrusive" technologies such as video and radar, have been recommended in this report. The ISTEA requirement for the Management Systems was later scaled back by subsequent legislation, but INDOT, like most other states' DOTs, are continuing with the development and implementation of management systems to fulfill state needs.

Continuous Counts (ATRs)- The best criterion for grouping ATR sites, and the number of additional ATRs required and their appropriate locations, for each count type, were determined: For traffic volumes, the existing INDOT grouping, which considers the area and functional classes of the ATRs, was chosen. The existing 92 traffic volume ATR sites were found to be adequate. The current seasonal factors used to annualize short-term volume data, derived using the existing INDOT group list, are therefore appropriate. A combination of regional and functional classes was found to address state-wide vehicle classification ATR data in the best manner. A large number of additional classification sites are needed. Upgrading of the existing volume-counting ATRs and speed monitoring sites to classification-monitoring capabilities before establishing completely new vehicle classification ATR sites is recommended. For truck weights, the criterion based only on functional classes was selected, and this calls for a small number of additional truck-weighing ATR sites to supplement the current number of WIM stations .

Coverage Counts- The number of short-term coverage counts for the Highway Performance Monitoring System (HPMS) and the County Flow Map (CFM) system, over a three-year cycle, were assessed for their adequacy. Also, the accuracy and adequacy of equipment used for this activity were evaluated.
The existing volume and classification coverage activities cover all HPMS sample sections although a lack of resources sometimes limits the frequency at which data is collected. The HPMS truck weighing subprogram is currently in an experimental stage, and a life-cycle cost analysis framework has been devised for determining the optimum equipment use for this activity, in the event that weight data becomes a reporting requirement for HPMS. Based on revised frequencies for coverage (CFM) counts on roads on the National Highway System (NHS) as well as roads in high growth counties, a new schedule for coverage (CFM) counts has been proposed, and additional resources needed to implement the new schedule have been determined. Documentation of field operations relating to equipment accuracy and testing has been carried out in this study, and recommendations have also been made to improve certain aspects of these field operations.

Vehicle Classification on Segments of the National Highway System (NHS)- Currently, INDOT has no specific program to monitor classification on segments on the NHS. Rather, use is made of other count programs (i.e., ATR and coverage counts) at sites that overlap with the NHS network. An evaluation of such monitoring activities on the NHS network revealed that classification on most NHS segments is carried out by at least one count program, albeit over a 5-year cycle. The current cycle duration for vehicle classification on NHS segments will be reduced to the required maximum of 3 years after the recommendations for coverage count frequencies and upgrading of existing volume-counting ATRs, are implemented. The few NHS segments that could not be monitored even over the current five-year cycle have problems relating to traffic flow: The very fast nature of traffic at such segments precludes the performance of reliable classification or volume counts by the usual equipment used for such counts. Such segments should be monitored using improved sensor technologies or “non-intrusive” technology for a minimum duration and frequency required for classification activities on the NHS.

Database System- The large volume of data that is expected to be generated after implementing the recommendations of this study means that an appropriate database system that would effectively address all stages of data management is needed. Current methods of managing data are inadequate and need to be upgraded with a database system. Additional hardware has been recommended to improve the existing network architecture, while new software systems for data management, i.e., TRADAS and GIS, have been suggested. Two additional staff are needed to manage these software systems. Appropriate storage media and data retention lengths for data from the various count programs have also been addressed.

Office Factoring and Field Procedures- Current INDOT procedures for data summarization, reporting, and calculation of adjustment factors such as the Seasonal Adjustment Factor, the Growth Factor, and the Axle Correction Factor, have been studied and documented in this study. The existing procedures for field measurements and data

collection activities have also been evaluated and documented. Recommendations have been made where the existing methods of data summarization and data collection fall short of standards set by established agencies.

Vehicle Occupancy- Given the difficulty involved in collecting such data, efforts to solicit the assistance of MPOs in collection of vehicle occupancy data is emphasized. The use of data already available in the Indiana Crash Database is also recommended.

Conclusion- The existing structure of INDOT's traffic monitoring program is generally such that many of the TMS/H requirements are already in place, as shown by the findings of this study. With a demonstrated commitment to implement recommendations from this study that would address the very few areas needing attention, INDOT would be in a position to obtain concurrence of the FHWA for its Traffic Monitoring System.

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LIST OF ABBREVIATIONS

AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ATR	Automatic Traffic Recorder
BMS	Bridge Management System
CFM	County Flow Map
CMS	Traffic Congestion Management System
DOT	Department of Transportation
FHWA	Federal Highway Administration
GIS	Geographical Information System
IMS	Intermodal Facilities Management System
INDOT	Indiana Department of Transportation
ISTEA	Intermodal Surface Transportation Efficiency Act
JTRP	Joint Transportation Research Program
HPMS	Highway Performance Monitoring System
MADT	Monthly Average Daily Traffic Volume
MATW	Monthly Average Truck Weight
MAPT	Monthly Average Percent Trucks
MPO	Metropolitan Planning Organization
NHS	National Highway System

OFE	Other Freeways and Expressways
OPA	Other Principal Arterial
PMS	Pavement Management System
PTMS	Public Transportation Facilities and Equipment Management System
SAS	Statistical Analysis System
SMS	Safety Management System
TRADAS	Traffic Data Analysis System
TMG	Traffic Monitoring Guide
VDT	Vehicle Distance Traveled
WIM	Weigh-in-Motion

1.0 BACKGROUND INFORMATION

This study was carried out as part of the Joint Transportation Research Program (JTRP) between Purdue University School of Civil Engineering and the Indiana Department of Transportation (INDOT). The execution of the project and preparation of this report was carried out by Samuel Labi, a graduate research assistant, under the supervision of Professor Jon D. Fricker, of the School of Civil Engineering. The section labeled DAP F was carried out by Amr Mahmoud, a graduate research assistant.

1.1 Problem statement :

Section 1034 of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 required States to develop, establish and implement six management systems and a traffic monitoring system for highways. The six management systems are for:

1. Pavement on Federal-aid highways
2. Bridges on and off Federal-aid highways
3. Highway safety
4. Traffic congestion
5. Public transportation facilities and equipment
6. Intermodal transportation facilities and equipment

In the *Federal Register* of 1 December 1993, an Interim Final Rule was published to specify implementing regulations for the six management systems and the traffic monitoring system. The intended effect of the regulations was to improve the efficiency and safety of, and protect the investment in the nation's transportation infrastructure.

In this edition of the *Federal Register*, Chapter 1, Subchapter F (Transportation and Infrastructure Management) Part 500 (Management and Monitoring Systems), Subpart H (Traffic Monitoring Systems For Highways) Section 500.805 (a) of Subpart H, it is stated: "Each state shall develop, establish and implement, on a continuing basis, a Traffic Monitoring System for Highways to be used by Federal departments, agencies, states, local departments and public and private agencies [when] such data are used in

support of the management systems … [and when] the data are used in support of studies or systems which are the responsibilities of the US Department of Transportation."
Section 500.805 (b) of Subpart H states: "The Traffic Monitoring System for Highways should be based on concepts described in the *[AASHTO] Guidelines for Traffic Data Programs* and the *Traffic Monitoring Guide,* and shall be consistent with the *HPMS Field Manual*."

Each of the management systems require good data to be effective. The key question is: Are the traffic data that are currently collected by INDOT adequate in terms of amount and accuracy, and are such data current enough to meet the needs of the management systems? Furthermore, are the data collected and stored in a format conducive to retrieval and analysis without extraordinary effort?

To answer these and related questions, INDOT's Roadway Management Division established a project to determine the data needs of the ISTEA management systems and to assess the Division's capability (at current staffing and funding levels) to meet these needs. The work elements of this project, which are listed in the Work Plan Approach of this report, are based on the numbers of the paragraphs in Section 500.807 of the December 1, 1993 issue of the Federal Register, pages 63484-63485, that describe the components of a TMS/H study.

The requirement for the management systems was later scaled back by subsequent legislation. However, INDOT, like most other states' DOTs, is continuing with the development and implementation of the management systems to fulfill state needs.

1.2 General Scope of Work :

This study focused on all three dimensions of the traffic data management: kind of count program, type of traffic count, and stage of work.

The continuous and coverage count programs were evaluated for the type, adequacy, condition, location and appropriateness of the present traffic monitoring sites under these

programs. This evaluation is necessary because of the recent extensive revisions that have been made to the functional classification system. Findings of two recent studies -- Estimation of Statewide Vehicle-Miles Traveled and Estimation of Statewide Origin-Destination Tables from Count Stations -- have confirmed the need for additional well-placed traffic count stations. A series of earlier studies such as the "Growth Factors" studies, that made extensive use of count data, indicated the need for a comprehensive update of the monitoring site locations. The Special Needs program was also evaluated briefly, especially from the traffic data needs perspective.

For each count program, the following count types were studied: Traffic volume, vehicle classification, and truck weight. Other count types, such as vehicle speeds, were not studied.

All stages of work, i.e., data collection, data analysis and processing, data reporting, and data retention, for each count type of the various count programs, were evaluated for equipment and staffing needs, and general procedural accuracy.

1.3 Work Plan Approach :

The requirements of 23 CFR Part 500, Subpart H - Traffic Monitoring System (TMS/H) of the December 1, 1993 issue of the *Federal Register*, were initially addressed under Volume 3, chapter 11 of the FY 1994 Highway Planning and Research Program (HPR) entitled "Evaluation of Traffic Monitoring Programs and Feasibility Study of a Traffic Monitoring Database".

This study investigated the relationship between data needs and data collection capabilities. This was done in several ways. Individuals active in the development of the various management systems were asked for the nature of current and anticipated data needs of their management systems. Government manuals, journal articles, conference proceedings and results of previous research were examined for guidelines and ideas. Companies that provide services and equipment related to traffic data collection were asked for product information and, in some cases, requested to demonstrate their

product's performance. Information was also obtained from various responsible personnel at various levels of the current data collection, analysis, reporting and retention processes at INDOT. The Metropolitan Planning Organizations (MPOs), who are responsible for traffic data collection in urban areas, were contacted to provide requisite information in areas that fall within their jurisdiction. Research was also carried out on the World Wide Web, as home-pages of various government agencies and equipment manufacturers were visited to obtain updated information.

The data action plans, which evolved from the original problem statement and objectives of the study, are listed below:

Data Action Plan B1: Adequacy/accuracy of the existing data collection process to satisfy the needs of the Pavement Management System (PMS).

Data Action Plan B2: Adequacy/accuracy of the existing data collection process to satisfy needs of the Bridge Management System (BMS).

Data Action Plan B3: Adequacy/accuracy of the existing data collection process to satisfy the needs of the Traffic Congestion Management System (CMS).

Data Action Plan B4: Adequacy/accuracy of the existing data collection process to satisfy the needs of the Highway Safety Management System (SMS).

Data Action Plan B5: Adequacy/accuracy of the existing data collection process to satisfy the needs of the Intermodal Facilities Management System (IMS).

Data Action Plan B6: Adequacy/accuracy of the existing data collection process to satisfy the needs of the Public Transportation Facilities and Equipment Management System (PTMS).

Data Action Plan B7: Adequacy/accuracy of the existing data collection process to satisfy the needs of the Highway Performance Monitoring System (HPMS).

Data Action Plan C: Verification of the adequacy/accuracy and locations of existing continuous traffic counting equipment as related to vehicle volumes, weights and classifications.

Data Action Plan D1: Verification of the adequacy/accuracy and frequency of existing short term traffic counting equipment and counts, respectively.

Data Action Plan D2: Verification of the adequacy/accuracy and frequency of existing vehicle classification activities on National Highway System.

Data Action Plan E: Definition of the needs/processes and frequency required for vehicle occupancy monitoring.

Data Action Plan F: Validation of the accuracy of existing traffic counting equipment, including preparation of procedural guidelines for equipment testing.

Data Action Plan G: Verification of the adequacy of the existing database to accommodate additional vehicle data requirements, investigation of alternative database options, and selection/recommendation for a new database system, if deemed appropriate.

Data Action Plan H1: Validation of the accuracy. of existing short-term traffic data collection/analysis processes and procedures utilized in office factoring adjustments.

Data Action Plan H2: Documentation of existing short-term traffic data collection and analysis processes and procedures utilized in office factoring adjustments.

General Data Action Plan: Verification of the adequacy/expertise of existing INDOT staff to accommodate the needs of a Traffic Monitoring System, definition of traffic

counting equipment and database needs by quantity, type and dollars, and drawing up of a budget for the acquisition of equipment needs that are defined.

The Data Action Plan (DAP) for each work activity consists of a) a description of the data needs of that activity, b) an appraisal of INDOT's current data collection activity that would respond to the data needs, and c) a recommendation as to what additional personnel, equipment, and/or funding (if any) are needed to meet those needs. As mentioned in several of the DAPs, it is often the case that a particular traffic data collection activity or resource is applicable to more than one work element. For this reason, the description of these activities has been placed in numbered appendices, rather than being repeated for each DAP. Also, some recommendations that have been made are applicable to more than one management or monitoring system. Therefore, a summary of the recommendations has been provided as part of the final data action plan.

2.0 INTRODUCTION

2.1 General Overview

Highway infrastructure continues to play a pivotal role in the overall economy in the State of Indiana. An effective road network is considered indispensable in this state, given the strategic location of the state. At various stages of analysis, evaluation, and decision-making in highway management (such as planning, design, finance, safety, congestion and air-quality), reliable traffic data are a vital and indispensable input. A list of typical reports generated by INDOT's traffic monitoring program is attached as Appendix 7, and examples of the uses to which reported data are put is shown as Appendix 9.

In 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) was signed. One of the requirements of this Act was the establishment and implementation of a traffic monitoring system for the highways in each state. Such a system would ensure that reliable and good quality traffic data are collected. Such data are critical for proper estimation of technical and economic consequences of various highway management strategies. In this way, priorities for investment of resources can be identified, with a view to allocating funds to protect the huge investments already made in the state's highway infrastructure.

According to the *Traffic Monitoring Guide (1994)*, the overall structure of traffic monitoring should consist of three major elements:

a) A relatively limited Continuous Count program,

b) An extensive Coverage Count program, and

c) A flexible Special Needs program.

Each of these programs consists of sub-programs to measure relevant traffic characteristics, i.e., traffic volume, vehicle classification and truck weight. The Guide offers procedures for the development of a statistical sampling program to estimate these traffic characteristics with specified levels of reliability.

The FHWA further recommends that the philosophical approach to the development of a traffic monitoring system for highways should follow the systems analysis concepts of holism and parsimony. Holism expresses the idea that the whole is much more that the sum of its parts, i.e., program integration is far superior to program separation. Parsimony is the quest for the simplest and the most economical valid solution.

Against these backgrounds, the development of a traffic monitoring system for any state is expected to:

(a) be built around the existing traffic monitoring system into which the state has already invested a great deal of resources,

(b) ensure that resources, such as a recording station or personnel, can be used for more that one element of the state's traffic monitoring program,

(c) take advantage of nested operations offered by equipment that generate auxiliary data beyond the primary data, e.g., separate classification and volume counts are not needed at weigh-in-motion sites because WIM equipment collect such data as well, and

(d) be such that special request counts at a particular site are carried out only if information required for that site cannot be obtained from existing continuous or coverage counts, and coverage count programs.

This study is aimed at developing a traffic monitoring system for highways (TMS/H) for the State of Indiana. This effort was not entirely new, but rather involved validating existing procedures, identifying deficient areas, and recommending appropriate remedial measures for areas where the existing system falls short of expected standards. With the implementation of the recommendations of this study, it is expected that the transition of INDOT's current traffic monitoring program to a full traffic monitoring system would be realized. The experience of other States in TMS/H development is briefly discussed in Appendix 6.

2.1.1 Structure of INDOT's current traffic monitoring program

According to the *Traffic Monitoring Guide* of the FHWA, page 3-2-2, "the first step in reviewing any … program is to define, analyze and document the existing situation, because a clear understanding of the present program will increase confidence placed on later decisions to modify the program." The TMG further recommends that such a review should explore the historical design, procedures, equipment, personnel and uses of information.

The overall structure of INDOT's Traffic Monitoring Program can be illustrated as a cube with each face divided into three dimensions: one dimension representing count programs (continuous, coverage, and special needs); another dimension representing count type (volumes, classifications and weights); and the third dimension representing stage of work (data collection, data analysis, and data reporting/retention).

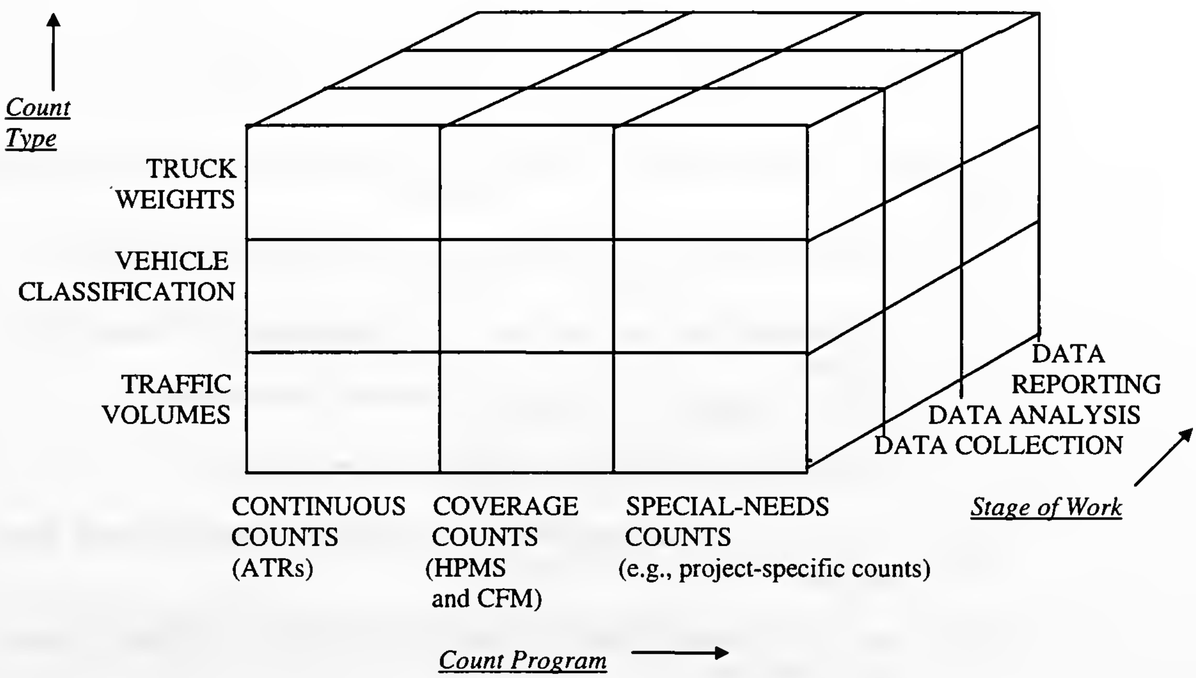
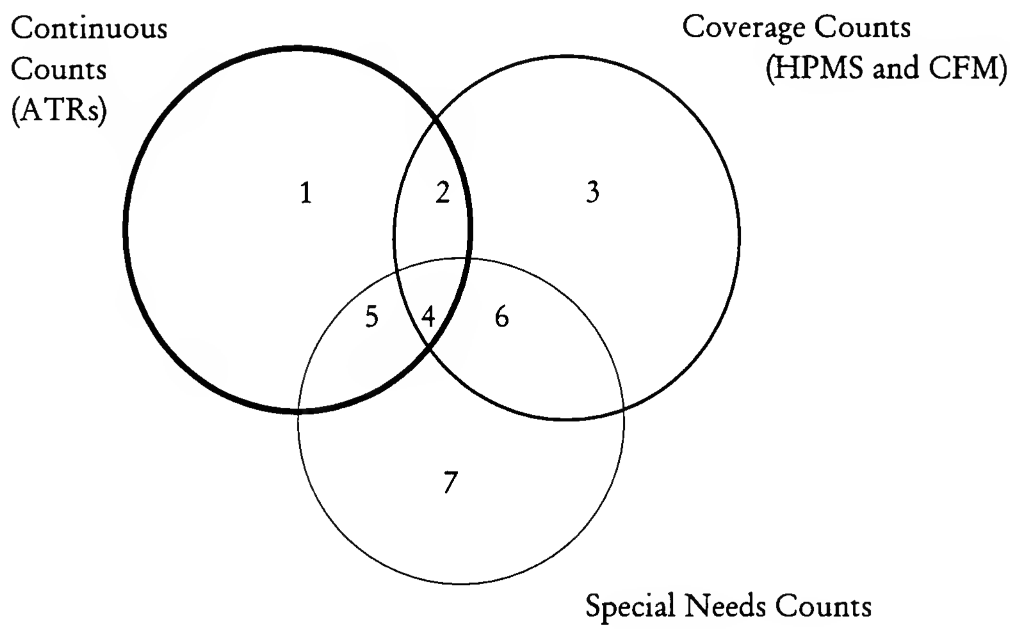


Figure 2.1.1 (a) Schematic illustration of the various dimensions and aspects of INDOT's Traffic Monitoring System

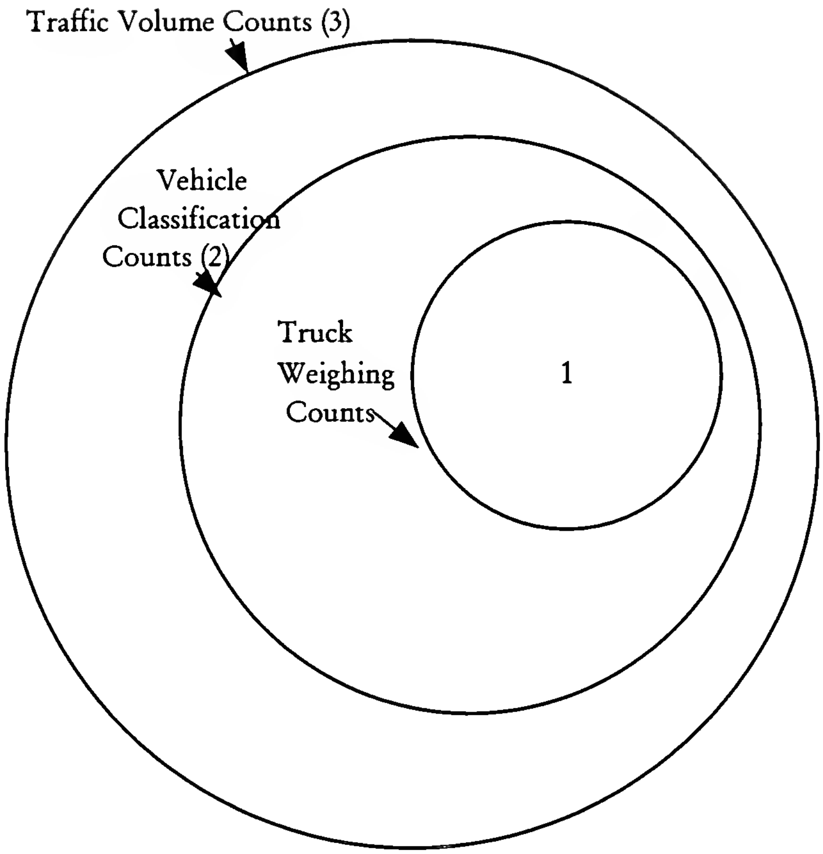
In reality, these cube cells do not exist as discrete as the figure above may suggest, but actually overlap with each other in all directions, while some cells are nested in others, as

evidence of the parsimonious and holistic approach adopted by INDOT in its traffic data collection activities. This is illustrated in figures 2.1.1(b) and 2.1.1(c) shown below.



Region	Description
1	ATR sites that generate data used only by the Continuous Count program
2	ATR sites that generate data used by the Continuous and Coverage Count programs
3	Short-term coverage counts of use to the HPMS and CFM programs
4	ATR sites that generate data used by all three count programs
5	ATR sites that generate data used by the Continuous Count and Special Needs programs
6	Short-term coverage (HPMS and CFM) counts of use to both HPMS/CFM and other special needs
7	Count sites set up for a special need and do not fall under Continuous or Coverage count programs. These are often project-specific counts such as turning movements, and counts specifically requested for by some other agencies and management systems, and for research purposes

Figure 2.1.1 (b) Illustration of overlapping nature of data-use by count programs



Region	Description
1	Truck-weighing equipment that also measure vehicle classification and traffic volumes
2	Vehicle-classification equipment that also measure traffic volumes
3	Equipment that only measure traffic volumes

Figure 2.1.1 (c) Nested structure of counts made available by appropriate equipment

Figure 2.1.1 (b) provides an illustration of the recommended overlap of the three count programs in order to achieve an integrated traffic monitoring system that is both holistic and parsimonious in its structure and function. The Special Needs Count program is built around the Continuous and Coverage Count programs. That is, requested counts for a special need at a particular location are not carried out unless it is established that the data required at that site are not available because there is no ATR site or recent and representative short-term count at that location.

2.1.1.1 Count programs :

Continuous Counts: Data collection for the continuous count program is carried out by permanently-installed and automated traffic recorders (ATRs). As of November 1997, there were 34 weigh-in-motion and 58 telemetry sites, distributed all over the state. This equipment continuously collect traffic data and relays such data by modem on a daily basis to INDOT central office, where data analysis and processing are carried out. The ATR equipment is characterized by high initial cost and relatively low operating costs.

The Continuous Count program has a long history, and its development has been evolutionary and incremental in nature: The distribution and locations of the weigh-in-motion ATRs (WIMs) were guided by the needs of the Strategic Highway Research Program (now called the Long Term Pavement Program) and therefore considered pavement type in the distribution. Telemetry sites were chosen by INDOT in an effort to adequately capture trends in vehicle movement on the various functional classes. The objectives of INDOT's continuous count program, which translate to the number and location of the ATR sites, include generation of data for the management systems, and development of appropriate factors to monitor fluctuations in traffic characteristics due to growth, seasonal patterns, etc. Details of equipment used for continuous counts are found in

Appendix 1. A sample ATR site information sheet is attached as Appendix 11, while sample output data from ATR stations is provided as Appendix 12.

Problems associated with the current continuous count program include too few sites, and the lack of a comprehensive program for equipment testing and calibration. These problems are addressed in this study.

Coverage Counts: Extensive state-wide short-term counts are carried out for the County Flow Map (CFM) system and other uses. This is a detailed program that monitors every segment of the state road system. The HPMS count program can be considered a subset of the CFM counts. Coverage (CFM) count data are used to supplement HPMS data to arrive at more precise and more detailed estimates of travel throughout the state. The Coverage Count program is often described as the basic planning data collection tool in the state.

The HPMS is a nation-wide inventory system that assesses the operating characteristics, among others, of highway infrastructure to support the functions and responsibilities of the Federal Highway Administration. Counts are carried out at a duration of 48 hours, and over a count cycle of 3 years. There are currently about 6000 HPMS universe sections in the State of Indiana. Out of these, about 2700 have been designated HPMS sample sections. Over the three-year cycle, all the sample sections are monitored for traffic volumes, while the TMG suggests that 300 and 90 sections should be monitored for vehicle classification and truck weight, respectively.

For the coverage counts, portable counters and road tubes are used, but in recent times there is a growing tendency, especially on the part of the MPOs, to use magnetic imaging equipment for such counts. Details of equipment used for coverage counts are found in Appendix 1. Samples of coverage count reports for vehicle classification and traffic volume are attached as Appendices 13 and 14

respectively. A sample sheet from the County Flow Map publication is provided as Appendix 10.

Factors obtained from the Continuous Count program are applied to short-term data collected by the coverage counts in order to arrive at summarized and annualized statistics that are used by the management systems and other end-users.

For the HPMS, INDOT has implemented a mechanism through which the required sample size for the current year and for any future year can be assessed. Using this mechanism, INDOT should continue to evaluate the adequacy of counts sites periodically. This is done by using a formula that relates the required number of sample sites to the variation of AADTs of HPMS sections within each volume group of each functional class and the required precision.

For the CFM, continued emphasis should be given to roads of higher priority such as Interstates, and this priority could be extended to all roads on the National Highway System and to roads in counties that are expected to have relatively higher traffic growth.

These considerations would enable INDOT to achieve statistical validity of data for HPMS, ensure that data are collected where they are most needed for the CFM, to achieve overall economy in the data collection activities, and to plan ahead for requisite resources to meet expected levels of traffic monitoring for the standard sample at future years.

Special Needs Counts Program: Other counts that are not covered under the continuous or coverage count programs, fall under the flexible "special needs" category. Project-specific counts fall under this category. Also, such special needs may be indicated by some management systems and research divisions. The duration and frequency of such counts are specified by the person making the request. Most of such "external" agencies obtain traffic data from the existing

continuous and coverage count programs. However, some of these agencies often need additional traffic data beyond what is already offered by the existing regular programs, and thus require special counts to satisfy their extraneous needs. According to the *Traffic Monitoring Guide*, the purpose of the Special Needs program is to complement and complete the entire traffic monitoring program by providing adequate flexibility to address any additional traffic data needs.

2.1.1.2 Count types

Traffic Volumes: Provides an indication of the number of vehicles passing a given spot, or that use a particular network system within a specified time interval.
Vehicle Classification: The sorting of vehicles into a fixed set of categories, and the subsequent provision of a scheme of logical relationship between categories.
Truck Weights: These counts gives an indication of the magnitude and frequencies of loads imposed upon a highway facility.
Other traffic data types such as speeds were not included in this study.

2.1.1.3 Stage of Work

Data Collection: For continuous counts, data collection is carried out using automatic traffic recorders (ATRs) permanently installed at various locations on the state road network. This equipment automatically collects and relays traffic to INDOT central office for data analysis and processing. ATR equipment basically consists of an assembly of axle sensors and inductive loops permanently embedded in the road surface. For coverage counts, pneumatic road tube equipment, installed by mobile field crews, are used. The tubes are placed at right angles to traffic lanes across the roadway with one end plugged. The tubes are connected to a weather-proof and compact main processing unit located at one side of the roadway. Appendix 1 shows the current inventory of data collection equipment used by INDOT and the MPOs, while staff responsible for data collection activities are shown as Appendix 2.

Data Analysis: Involves the calculation of adjustment factors from the continuous counts and application of these factors to short-term coverage count data to arrive at summary statistics such as Annual Average Daily Traffic(AADT) and Vehicle Distance Traveled (VDT). Also involves estimation of other site-specific and system-level statistics. Hardware and software currently used for data analysis include IBM XT Mainframe and IBM personal computers, International Road Dynamics (IRD) Traffic Data Software, and Microsoft Excel (see Appendix 3). Using such software, it is possible to query traffic data by count type and selected time intervals, e.g., ESALs by vehicle class by day of week. Appendix 3 and 4 show the equipment and staff currently used for data analysis and processing.

Data Reporting: The submission of traffic data to management systems, federal agencies and other end-users in prescribed formats. The use of a Geographical Information System for reporting of traffic data has been recommended, to facilitate querying operations, and for users to view traffic patterns and characteristics in a spatial context.

A chart showing the sequence of work for various programs and the relationships between various work items is shown as Appendix 15.

In line with the principles of "holism & parsimony" suggested by FHWA's *Traffic Monitoring Guide (1995)*, part of the overall objectives of this project is to ensure that INDOT's traffic monitoring program is structured such that:

a) some stations serve more than one count element, e.g., the ATR station designated *Hamilton 5260* (near Noblesville) lies on an HPMS sample section, hence it provides data for both Continuous Count and Coverage Count programs.

b) some equipment collect more than one count type, e.g., the weigh-in-motion station designated *Laporte 4240* collects data on traffic volumes and vehicle classification in addition to truck weights.

c) some staff and personnel collect, analyze and report data of more than one count type and for more than one count program, e.g., INDOT's current traffic data collection supervisor is responsible for overseeing the collection of volume, classification and weight data for both Coverage and Continuous counts.

The attainment of these objectives of this study and the implementation of concomitant recommendations would enable the INDOT to:

- ensure that only high-quality and statistically reliable engineering data are collected and reported, in the most appropriate and convenient format, to end-users
- coordinate its data collection efforts across count types and across count elements, to reduce duplication of effort and resources
- achieve overall economy in data collection activities
- plan ahead to meet future requirements of count programs

DRAFT TMS/H Data Action Plan **B1**
Pavement Management System (PMS)
Samuel Labi and Jon D. Fricker
September 21, 1998

INDOT Contact Person:
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INDOT Work Plan Activity: *Adequacy/ accuracy of existing data collection process to satisfy traffic data needs of the Pavement Management System.*

23 CFR Chapter 1, Subchapter F (Transportation and Infrastructure Management), Part 500 (Management and Monitoring Systems), Subpart B (Pavement Management System) Section 500.207(a), *Federal Register*, 1 December 1993, p. 63478: "The PMS for the National Highway System (NHS) shall, as a minimum, consist of ...(1)(iv) Traffic information including volumes, classification, and load data." Section 500.207(b) states: " The PMS for Federal-aid highways that are not on the NHS shall be modeled on the components described in paragraph (a) of this section ..."
Also, subpart H (Traffic Monitoring Systems for Highways), Section 500.807(b), *Federal Register*, 1 December 1993, p.63484: "Traffic Data ... shall be to the statistical precision ... specified by the data users..."

With the acceptance of the Interim Final Rule (*Federal Register*, 19 December 1996), numbering of the above-quoted sections has been changed as follows: Section 500.207 is now 500.106, and Section 500.807(b) is now 500.204(b).

A. TRAFFIC DATA NEEDS

1. **Type of data required**:
   - Traffic volumes (AADT, and truck volumes)
   - Vehicle classification (% trucks)
   - Load data (Truck weights, weight distribution by axle type, etc.)

2. **Location of data collection sites**
   - On NHS routes and state roads, between every major intersection or interchange.
   - At specific locations requested by the operators of the PMS.

The *Federal Register*, in its December 1993 issue, defines a Pavement Management System as " ... a systematic process that provides, analyzes, and summarizes pavement information for use in selecting and implementing cost-effective pavement construction, rehabilitation, and maintenance programs". According to the *Federal Register*, one of the functions of a Pavement Management System is maintaining a database that includes

traffic information on volumes, vehicle classification and loads. The types of data indicated above are used to estimate the impacts of traffic loading on the condition and expected remaining life of a highway section's pavement. AADTs are routinely collected by INDOT through its continuous count stations and coverage count program, but truck data are not so readily available. A common way to characterize and quantify this damage is the calculation of equivalent single axle loads (ESALs). The ESAL calculations involve converting actual axle loads applied to the pavement surface into equivalent multiples of 18,000-pound single-axle loads. However, INDOT's contact person for PMS has stated that volumes and weights of only truck traffic are sufficient for the state's current PMS, so detailed data on axle loads and ESAL calculations for other vehicle types, are not needed.

It is envisaged that a model for forecasting future AADTs based on historical trends would be of use to the PMS. The data required to build and apply such a model could be obtained from the existing ATR and coverage count programs.

B. INFORMATION ON THE EXISTING SITUATION

1. Data collection equipment and sites.

Currently, the best source of truck weight data is INDOT's system of 34 Weigh-in-motion (WIM) on the state's road network. Each WIM site has axle sensors, steel pads, and inductive loops permanently embedded in the road surface as vehicle detectors. This equipment, which continuously collects data on traffic volumes, vehicle classification and vehicle loads, operates through a central control station at INDOT's central office, and communicates daily with the field stations through standard dial-up lines.

WIM equipment collects data that satisfy the special needs of the PMS, but the main purpose of this equipment is to fulfill the state's Continuous Count program and the special needs of the Long Term Pavement Performance (LTPP) program. Furthermore, this equipment has the potential of partially fulfilling possible future needs of the truck weight aspect of the HPMS coverage count program, in the event that this data type becomes a reporting requirement for the HPMS.

Information on the type, manufacturer, years in service and reliability of equipment at each WIM station, is provided in the table attached as Appendix 1. The Southport (Indianapolis) site has piezo-electric WIM equipment. WIM equipment at many other sites is of the bending plate type. One of the WIM sites on the I-70 has single-load cell equipment. This type of equipment is considered the most durable and accurate WIM system currently available on the US market.

2. Data collection personnel

The table attached as Appendix 2 shows the various personnel currently responsible for collection of traffic data for all elements of INDOT's traffic monitoring program.

C. EVALUATION OF THE EXISTING SITUATION.

At the existing 34 WIM sites, data on speed, class, gross weight, axle spacings, and axle weights of individual vehicles, and summary reports for the traffic stream can be generated. While potentially a source of valuable data, these sites have some shortcomings:

a. It is not unusual for a WIM station to be out of order or in need of re-calibration.

b. Many of the WIM sensors have been installed in only one lane of a multi-lane highway section.

c. Several of the 34 WIM stations were located because the pavement types at those locations were of interest to the Strategic Highway Research Program (SHRP), which has evolved into the Long Term Pavement Performance (LTPP) Program.

d. Even if all the 34 WIM sites were distributed across the state in the most representative way possible, it seems unlikely that so few sites could adequately describe truck traffic on all the major routes in the state's highway system.

While it would be desirable to have detailed truck counts and weight data throughout the state, the minimum PMS data needs are described by INDOT's Contact Person for the PMS as follows:

- Location: On state highways and other routes on the National Highway System (NHS).
- Level of detail: At most for every segment between major intersections and interchanges.
- Average Daily Traffic.
- Vehicle classification: Two classes, viz., cars (classes 1-3) and all other vehicles greater than class 3.
- Truck Weights: Development of an appropriate summary statistic which indicates load. While ESAL is such a statistic, it is dependent on pavement structure which is not always known. (This requirement, strictly speaking, is a data analysis and processing requirement rather than a data collection need.)
- Precision: Truck counts to the nearest 100 per day. Truck weights could be average empty and average full.
- Format: Reported data should be tied with location for relational purposes, e.g., Reference Post 218+38 on Interstate 65.

In line with TMG-recommended holistic and parsimonious approach to the allocation of resources to states' traffic monitoring programs, it is recommended that the needs of the PMS should, as much as possible, be fulfilled by making use of the available resources and facilities offered by the existing programs such as the coverage and continuous counts. This way, needless duplication of resources and effort in the overall data collection program could be avoided.

In this regard, special counts for PMS would be necessary only when it has been ascertained that collection of appropriate data at those locations are not covered, in all respects (duration, frequency, etc.) by the Continuous or Coverage count programs.

Data required by the Pavement Management System are currently furnished to the PMS either directly by INDOT's Traffic Statistics Division in response to PMS's specific requests for detailed or summarized data, or using information contained in relevant sections of various reports, publications and documents made available by the Traffic Statistics Division.

The main shortcomings of the data collection system in meeting the needs of the PMS is that of flexibility. ATR programs, according to the TMG, are limited in their coverage, as is INDOT's truck weight ATR program. In the present situation, any future spontaneous or even anticipated need of the Pavement Management System for data at a special location of interest and within specific time frame cannot be fulfilled if that location is not covered under the existing Continuous Count program. The current total reliance on permanently-installed weigh-in-motion equipment of the Continuous Count program for truck data, has resulted in lack of flexibility of the present system in fulfilling such potential needs of the PMS.

To address this issue, the procurement and deployment of adequate portable truck-weighing equipment is therefore strongly recommended, because this would permit the performance of special counts at sites of interest for the Pavement Management System and thus enable the generation of more reliable and representative data for pavement design, analysis, and monitoring.

A provisional program for portable truck-weighing has been suggested for HPMS as part of the Draft Action Plan for that system. Until the time that reporting of truck weight data becomes an HPMS reporting requirement, portable truck weight measurements could be carried out solely for the PMS.

Previous studies have associated portable WIM equipment with problems of accuracy. Hence a great deal of caution is necessary in the testing, calibration and operation of such equipment.

(c) The lack of some type of summary statistic that indicates load for pavement analysis. Current reporting of traffic data to PMS is done using ESALs. However, the problem with ESALs is that it is dependent on pavement structure, and that is not always known.

To date, the Pavement Management System is not fully developed. According to the INDOT contact person for this management system, data collection for assessment of pavement condition of the state roads has been completed, and the management system for Interstate road pavements is reasonably complete. However, work on deterioration models for the National Highway System roads is yet to begin.

The nature and scope of future data collection needs of the PMS is not expected to change significantly from the present situation. INDOT's contact person for this management system states that in future, the PMS would require data that would enable it to develop highway usage trends as an effective measure of the service provided by roads and also to provide a better reflection of the effect of truck traffic.

According to INDOT's contact person for PMS, future needs regarding traffic data processing and reporting include an electronic detailed relational traffic data-base. From such a system, users could access information on traffic volumes, vehicle classification, and truck weights at any location with ease. This need is suggestive of the use of a Geographical Information System (GIS).

With the current extensive scope of the county flow map count program and with the implementation of the proposed revisions for the continuous and short-term truck-weighing programs as well as suggested improvements for data processing, INDOT would be poised to meet such future data needs of the Pavement Management System.

DRAFT TMS/H Data Action Plan **B2**
Bridge Management System (BMS)
Samuel Labi and Jon D. Fricker
September 21, 1998

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INDOT Work Plan Activity: *Adequacy/ accuracy of existing data collection process to satisfy traffic data needs of the Bridge Management System.*

23 CFR Chapter 1, Subchapter F (Transportation and Infrastructure Management), Part 500 (Management and Monitoring System), Subpart C (Bridge Management System) Section 500.307(a) and (b), *Federal Register*, 1 December 1993, p. 63478: " A state BMS shall include as a minimum, ... a data base and an ongoing program for the collection and maintenance of ... supplemental data needed to support the BMS ".
Section 500.303 states : " The modeling procedure [for BMS] accounts for traffic growth and deterioration..."
Also, Subpart H (Traffic Monitoring Systems for Highways), Section 500.807(b), *Federal Register*, 1 December 1993, p. 63484: "Traffic Data...shall be to the statistical precision ... specified by the data users ..."

With the acceptance of the Interim Final Rule (*Federal Register*, 19 December 1996) numbering of the above-quoted sections has been changed as follows: Section 500.307 is now 500.107, and Section 500.807(b) is now 500.204(b).

A. TRAFFIC DATA NEEDS

1. **Type of data required**:
    - Traffic volumes (AADT, and truck volumes)
    - Vehicle classification (% trucks)
    - Load data (Truck weights, weight distribution by axle type, etc.)

2. **Location of data collection sites**: Preferably at bridge sites, but this is not a requirement.

3. **Frequency and duration of data collection**: No special counts currently requested by BMS, but short-term counts from which relevant statistics are estimated should be carried out for a minimum of 48 hours, and at a minimum frequency of once every three years.

On page 63479 of the issue of *Federal Register* dated December 1993, a Bridge Management System is defined as "a decision support tool [for state bridges] that supplies analyses and summaries of data, uses mathematical models to make predictions and recommendations, and provides the means by which alternative policies and programs may be efficiently considered." According to this issue of the *Federal Register*,

"a BMS includes formal procedures for the collection, processing and updating of data, predicting deterioration, identifying alternative actions ..."

According to the INDOT contact person for this management system, vehicle classification and truck weights are necessary inputs for the user cost analyses for the state's bridge management system.

B. INFORMATION ON THE EXISTING SITUATION

1. **Data collection equipment and sites.**

Currently, there is no ATR equipment specifically installed for the BMS on any of the bridges in the state of Indiana. Rather, BMS makes use of data obtained from the coverage counts and from existing ATR equipment located at various points on the state's road network.

2. **Data collection personnel**

Table 2 in the Appendix shows the various personnel currently responsible for collection of WIM traffic data and traffic data for other count elements.

EVALUATION OF EXISTING SITUATION AND RECOMMENDATIONS

Even though the preferred locations of collected data are at bridge sites, there is no data collection equipment currently installed at any of the bridge sites in the State of Indiana. However, INDOT's contact person for this management system has stated that the location of data collection equipment at bridge sites, although preferred, is not a requirement, and that the current locations of the data collection equipment are satisfactory.

Because there is currently no special count program for the BMS, this management system obtains all its data needs from existing Continuous and Coverage count activities. Consideration is given to bridge locations when sites for INDOT's coverage counts are being chosen: short-term volume and classification sites are selected with due consideration given to locations that adequately represent traffic passing under or over a state bridge. This information is reported to the BMS. Currently, AADTs are reported to the BMS. These data are based on 48-hour counts carried out every three years and adjusted using factors derived from ATR data.

The current traffic-data collection efforts are generally adequate for meeting the current traffic data needs of the Bridge Management System. However, it is envisaged that this management system stands to benefit from the establishment of a portable weigh-in-motion program because such a program would allow data collection at specific locations preferred by the BMS. It would be impractical to monitor each of the 18,000+ bridges statewide, but data on truck traffic or even general traffic over any bridge of interest at a specific period, could be recorded using such equipment. The performance of such counts

would be in response to the submission of special request forms by the BMS to the INDOT Traffic Statistics Division. A sample of this form is attached as Appendix B4.1.

APPENDIX B2-1

TRAFFIC DATA COLLECTION REQUEST

Indiana Department of Transportation

Roadway Management Division

A. **Request Details:** 1. Submitted by: 2. Use of data: 3. Date of Request: 4. Last date for receipt of data: 5. Request number: 6. Other request details:	
B. **Site Details:** 1. Site description: 2. Terminal points of site: 3. County/City/Sector: 4. Other site details:	5. Sketch of site (if necessary):
c. **Details of Required data:** 1. Count Type: 2. Further details of Count type: 3. Desired period (if any) for data collection: 4. Duration: 5. Frequency: 6. Other details:	
General Remarks:	

This form is based on that provided on p. 23 of the AASHTO Guidelines for Traffic Data Programs.

DRAFT TMS/H Data Action Plan **B3**
Traffic Congestion Management System (CMS)
Samuel Labi and Jon D. Fricker
September 21, 1998.

INDOT Contact Person:
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INDOT Work Plan Activity: *Adequacy/ accuracy of existing data collection process to satisfy traffic data needs of the Traffic Congestion Management System.*

23 CFR Chapter 1, Subchapter F (Transportation and Infrastructure Management), Part 500 (Management and Monitoring Systems), Subpart E (Traffic Congestion Management System) Section 500.507(b), *Federal Register*, 1 December 1993, p. 63481: "A continuous program of data collection and system monitoring shall be established to determine and monitor the duration and magnitude of congestion ..."
Also, Subpart H (Traffic Monitoring Systems for Highways), Section 500.807(b), *Federal Register*, 1 December 1993, p.63484: "Traffic Data...shall be to the statistical precision ... specified by the data users ..."

With the acceptance of the Interim Final Rule *(Federal Register*, 19 December 1996) numbering of the above-quoted sections has been changed as follows: Section 500.507 (b) is now 500.109(b)(3), and Section 500.807(b) is now 500.204(b).

A. TRAFFIC DATA NEEDS

1. **Type of data required:**
   - Traffic volumes - AADT, system-level
     - Hourly or 15 minute volumes for specific sites
     - ADT, for specific sites
     - VMT, system level
   - Vehicle Classification (percent commercial vehicles)
   - Operating speeds and travel times

2. **Required location of data collection sites:**
   - System-level Counts
   - Site-specific Counts
     - -Permanent locations: a) Specific interchanges and intersections
       b) Specific locations or road sections
     - -Temporary locations: a) Road construction zones
       b) Special traffic generators

At each data collection site, data are needed for each lane and direction of travel. This study does not include traffic speeds, and therefore that need will be addressed under a separate study that is currently in progress.

3. **Frequency and duration of data collection:**

- For system level data, minimum frequency and duration of short term counts should be once in three years, and 48 hours respectively.
- For site-specific data, the operators of the Congestion Management System will specify frequency and duration of data collection at any site of interest.

On page 63480 of the December 1993 issue of the *Federal Register*, a Congestion Management System is defined as "... a systematic process that provides information on transportation system performance and alternative strategies to alleviate congestion and enhance the mobility of persons and goods." One of the components of a CMS, according to the *Federal Register*, is a continuous data collection and system monitoring program to determine the duration and magnitude of congestion and to evaluate the effectiveness of implemented actions. On page 63464 of this issue of the *Federal Register*, it is stated that the evaluation of performance measures for congestion alleviation requires data such as VMT by functional class and VMT by lane-mile.

In a paper titled *Congestion Management Data Requirements and Comparisons*, published in the Transportation Research Record 1499, Bryne and Mulhall emphasize the need to collect data on system usage and demand, such as VMT, average daily traffic (ADT), number of vehicles and duration of peak period. Such data, according to the paper, are necessary to measure congestion and to evaluate the efficacy of various strategies to reduce congestion and improve mobility. Also, Mark Hallenbeck and Nick Roach in a paper titled *Application of Automated Data Collection Systems for CMS Performance Monitoring*, stated that "Data collection is an integral part of any CMS. Data is needed to identify critically congested segments, evaluate system performance against adopted performance measures, and evaluate the effectiveness of CMS strategies once they are in place."

The types of traffic data indicated above are needed for analysis and processing to yield intermediate statistics such as day-of-week factors, axle correction factors and seasonal adjustment factors, which are of use to the CMS. Such traffic data are also needed for the computation of directional peak hour factors, directional factors, percentage of commercial vehicles (FHWA Class 4 and above), lane usage, and other statistics commonly used in congestion management.

B. INFORMATION ON THE EXISTING SITUATION

1. **Data collection equipment and sites.**

Table 1 in the Appendix shows details of the equipment that is used to collect needed traffic data for use by the Congestion Management System, other management systems, and other elements of the State's traffic monitoring program.

2. **Data collection personnel**
Table 2 in the Appendix shows the various personnel currently responsible for collection of data for the overall traffic monitoring system at INDOT.

C. EVALUATION OF THE EXISTING SITUATION
INDOT's contact person for the Congestion Management System emphasizes that the data collection effort for this management system should, as much as possible, reflect current conditions.
Data on system-level AADTs, vehicle classification, and hourly traffic volumes are currently collected under the existing Continuous (ATR) and Coverage (HPMS) count programs, and reported to CMS. However, given the limited extent of the ATR program, continuous count data reported to CMS may not reflect traffic conditions at specific sites of interest because such sites may be to far from the nearest ATR. Also, with the current 4-5 year cycle period for coverage counts, CMS may receive traffic data for a site whose most recent count may be up to five years of age. Even with the application of the necessary adjustment factors for traffic growth, such data may not reflect current traffic conditions. This problem is more readily felt in the case of site-specific data than for system-level data. This is due to the higher sensitivity of site-specific traffic characteristics to changes in land-use patterns and trip generation patterns. It is recommended that special request counts be carried out for specific sites of interest to CMS for which ...

a) the most recent count is over 1 year old, or
b) the most recent count is deemed too out-dated by CMS, or
c) there have been significant changes in trip making patterns in the vicinity of the site of interest since the time of the most recent coverage count at or near that site, e.g., construction of a new shopping mall.

Data collection at temporary sites of interest to CMS, such as road construction zones and special traffic generators, need to be carried out at the request of the CMS if such areas are not located near any existing ATR or recent coverage count location. Such special needs requests should indicate the desired duration of monitoring. A sample of the recommended form for such a request, based on the form provided on page 23 of the *AASHTO Guidelines for Traffic Data Programs*, is attached as Appendix B4-1 to this document.

For data to be collected at the permanent locations, no specific frequency and duration of data collection is required for the Congestion Management System. The INDOT Contact Person for this management system has indicated that any frequency and duration that would yield "reliable" estimates of AADT are acceptable.

However, for permanent sites at which hourly volumes and peak periods need to be determined in addition to AADTs, traffic data have to be collected and reported for each hour, and the duration of data collection must be consistent with the duration of congestion at that particular site or for a duration specified by the management system.

Permanent locations of interest to CMS may not fall under the sites for the existing continuous or coverage count programs, or even if they do, data they collect may not be readily available or retrievable over relatively short-spanned periods (e.g., 15 minute intervals) required by the CMS. According to INDOT's contact person for the Congestion Management System, "CMS does need the capability to monitor, collect, and provide traffic information on demand at intersections and interchanges to determine congestion levels." This statement reflects the need for special counts to be carried out for CMS at permanent special locations such as intersections and interchanges that are of interest to this management system using a specified count duration.

Currently, reporting of traffic data from ATR sites is done at intervals of 1 hour, even though monitoring is carried out continuously. This interval for reported data is considered too wide for assessment of congestion that may last for periods shorter than 1 hour. It is therefore recommended that intervals of reported data to CMS should be 15 minutes, or at an interval specified by the CMS for a particular site during the traffic peaking periods. In this regard, retrieval of hourly data, 15 minute data, or data at other specified intervals should be made, if possible, electronically. Hourly data is acceptable for other times of the day. Currently, such retrieval by CMS is a difficult task, because it can only be done by manual downloading.

The Congestion Management System requires that, in order for traffic data to be made suitable for use by available software, such data must be available by lane and by approach. The CMS also requires that accurate data be obtained at all sections of interest, including congested sections. However, a major drawback with existing data collection equipment such as detectors in pavement, is that such equipment are either incapable, or have been found to give inadequate or unreliable data at congested sites and multi-lane sections. This situation, according to INDOT's contact person for CMS, arises because current technologies in use rely on the availability of free-flowing traffic streams for effective collection of traffic data, a condition which is not usually associated with congestion.

It is recommended that more sophisticated traffic detection equipment such as video, radar, or microwave detectors, or other such equipment that use "non-intrusive" technologies, be procured to address such data collection problems associated with multiple lanes and congested sites. Several manufacturers of such equipment were contacted as part of this study. Also, reports on previous field tests carried out by several agencies on various equipment types and brands were reviewed as part of this study. A discussion of the review is provided on the next two pages.

According to INDOT's contact person for CMS, the format in which this management system prefers to receive traffic data is through PC spreadsheets and databases or through a Geographical Information System, because the formats offered by such systems facilitate data accessibility and retrieval.

Even with the purchase of new equipment, it is clear that the entire traffic data needs of the Congestion Management System cannot be fully satisfied by INDOT's traffic data collection program. This is because traffic congestion occurs on local streets and roads most of which are not the direct responsibility of INDOT. Data for many congested sites should be obtained from other sources, such as the Metropolitan Planning Organizations (MPOs) under whose jurisdiction such sites fall. According to the *Federal Register* (in its December 1993 issue), data bases and data sharing shall be integrated as necessary to achieve maximum utilization of existing and new data within and among agencies responsible for roadway, human and vehicle elements.

INDOTs contact person for CMS states that this management system, as at March 1997, is approximately 15% complete for the rural/small urban portions of the state, and about 45% complete for the urban/urbanized portions.

The use of video equipment or other appropriate non-intrusive technology is recommended to ensure the collection of good quality data for CMS. However, additional resources needed to address the current or future traffic data needs, from the "quantity" perspective, can only be assessed if the current and future scope of CMS is determined by the CMS staff. It is not expected that the types of data needed would significantly change from the present period to the time when the CMS is finally completed. However, the scope of data collection may increase as the development of the CMS nears completion and as more and more congested sections are identified.

"Non-intrusive" technologies for collection of vehicle classification data

For a long period of time, basic equipment such as pneumatic road tubes, inductive loops, and manual counts have been mainly used to collect vehicle classification data. These traditional methods generally perform well in rural areas. However, a study by Polk, Kraig and Minge, which surveyed the data collection methods of 12 state transportation agencies, showed that unique characteristics of urban areas pose the following severe limitations on the use of these traditional types of equipment in urban areas:

- There are not sufficient resources available for enough fixed counting stations to provide all traffic counts needed in an urban area. In addition, loop detectors are unable to measure certain useful traffic parameters, such as turning movement counts and weaving section movements.
- It is not safe for field personnel to conduct tube counts at sections where traffic volumes are high. Furthermore, road tubes do not perform satisfactorily on high-volume roads.
- Setting of road tubes on roads that have even moderate volumes can cause significant disruption to traffic flow.
- In some cases, road geometrics can make it difficult to obtain accurate counts using road tubes, such as locations of lane changing.
- Certain weather extremes can limit the ability of field staff to carry out counts. Also, road tubes tend to malfunction under very low and very high temperatures.

In recent years, new advances in technology have fostered a wide range of alternative equipment that have shown promise in overcoming some of the problems associated with the older equipment types. Such new technologies use ultrasonic, microwave or infrared energy, video, or magnetic fields. Most of these detectors can be mounted on poles by the side of a road or on overhead beams. Detectors using magnetic fields are usually small in size and can be planted in pre-constructed conduits in the pavement over which traffic passes.

Images sensed by most "non-intrusive" equipment are deciphered using various artificial intelligence algorithms. Descriptions of some equipment that use such technologies are provided below.

Descriptions of major vehicle-classification equipment that use non-intrusive technologies:

Traffic monitoring equipment that use non-intrusive technologies offer a much needed alternative to inductive loop systems. Sensors that are used by such technologies can be installed, operated repaired and reconfigured without lane closures or saw cutting the pavement surface. They are not prone to damage by construction, pavement resurfacing or trenching for installation and repair of utility lines. The major brands of vehicle-classification equipment that use non-intrusive technologies are:

- Autoscope Video Image Processor 2004, by Econolite/Image Sensing Systems
- Traficon Video Image Processor VIP-3, by Control Technologies
- Hi-Star NC-90A Magnetic Classifier, by Numetrics
- Remote Traffic Microwave Sensor (RTMS), by Electronic Integrated Systems
- Passive Infrared (PIR) Detector IR 250, by Advanced Sensing of Infrared Motion (ASIM) Engineering Ltd.
- Dual Technology (Passive Infrared/Doppler Radar) Detector DT 280, by Advanced Sensing of Infrared Motion (ASIM) Engineering Ltd.
- Active Infrared Laser Radar Model 780D1000, by Schwartz Electro-Optics

Descriptions of each of these equipment, obtained from their various product brochures, are provided below:

1. *Autoscope Video Image Processor, by Econolite/Image Sensing Systems, Inc., Anaheim, CA*

Autoscope was first introduced in 1987 as the first working application of "machine vision", with the intention of allowing area-wide vehicle detection and traffic parameter extraction without the high installation and maintenance costs of imbedded loop sensors. In subsequent years, the Autoscope technology has been refined to meet customer needs for performance and new functions. The core of the current model, Autoscope 2004, is an image processor -- a box that contains the micro-processor CPU, specialized image processing boards, and software to analyze the video images. The unit fits in an outdoor traffic cabinet and accepts images from multiple roadside video cameras. Using a mouse and interactive graphics, the user sets up Autoscope by placing "virtual detectors" on the video image displayed on a monitor. Each detector represents a zone -- either a wide area zone or a short zone that in the simplest form emulates an inductive loop. Once the

system is set up, one or more video cameras transmit road images to the Autoscope 2004 main processor and monitor, which digitize the image. A detection signal is generated each time a vehicle crosses a virtual detector on the monitor. This way, the Autoscope processor can analyze incoming video images to generate traffic data such as volume, speed, occupancy, headways, queue lengths, and vehicle classification. Vehicle length is the criterion used by the equipment to classify vehicles. Autoscope can be used for traffic monitoring of roadways as well as intersections.

The price of an Autoscope 2004 LE, that can be used for vehicle classification, is $24,000, and additional equipment (386 PC, camera and accessories) cost $2350 (ref: *Field Test of Non-Intrusive Traffic Detection Technologies*, presented at NATDAC '96 by Polk, Kranig, and Minge),

According to its product catalog, Autoscope is a proven system with installations at hundreds of sites in North America, Europe, and the Far East.

2. *Traficon Video Image Processor, by Control Technologies, Sanford, FL*
The Traficon video detection system is based on a three way coordination between the main system components, i.e., video cameras, traffic detectors, and transmission equipment. A video camera is installed at a height of 12-20 meters. Through a video cable, the video output of the camera is connected to the video input of the video detector. During set-up, detection lines/zones are drawn at the appropriate positions on the video image monitor. As a vehicle rolls over the detection lines, thus activating them, the vehicle is "detected" and the image is analyzed using specific algorithms that provide the necessary traffic data, including vehicle classification. With a board for video image compressing and decompressing (VIC), and a board for communication (COM), the transmission of images and data obtained by the detector to a remote traffic control center is made possible. Classification is carried out based on the length of vehicles. Traficon appears to be capable of monitoring both roadways and intersections effectively. Standard NEMA and 170 Cabinet Assemblies, currently used by many States for counting purposes, can be upgraded to carry out video detection by inserting the Traficon VIP-3 Video Detection Module. The founder of this company, in direct correspondence with the researchers of this study, stated that Traficon has a successful history of providing Video Detection Systems in Europe, with over 1,000 units installed in the last eight years, and that with the introduction of the versatile VIP-3, Traficon is poised to make an impact on the US market. The price of this equipment is currently not available to the researchers of this study.

3. Hi-Star NC-90A Magnetic Classifier, by Numetrics, Uniontown, PA
The Hi-Star NC-90A is described by its manufacturer as "the ultimate, complete, self-contained traffic classifier/analyzer." This equipment works on the principle of vehicle magnetic imaging with presence. Powered by re-chargeable Ni-Cad batteries, and housed in an impact resistant die-cast aluminum case, the NC-90A is capable of providing traffic data for short-term periods under heavy traffic conditions with little or no delay to traffic,

danger to field crew, inconvenience to motorists, and damage to the pavement. It is installed on the road surface by placing a metal protective cover over it and fastening the cover to the roadway using nails driven by a nail gun. No physical contact is necessary to collect accurate data. And the counters are normally installed in the center of the traffic lanes so that vehicles pass over the counter.

After the desired period of monitoring, the protective cover and the equipment are easily retrieved from the road surface using a small pry bar. The NC-90A is designed for three modes of operation: the Verify mode for provision of real time traffic analysis, the Frame mode which files each vehicle's speed and length into a particular pre-defined speed and length bin, and the Sequential mode which is used for in-depth studies that track vehicle movement in seconds, along with the vehicle's speed and length. Therefore, this equipment is capable of vehicle classification based on length. Hi-Star equipment may be programmed for data collection from any DOS compatible laptop, notebook, or PC.

The Numetrics magnetic imaging equipment are known to be somewhat vulnerable to interference from extraneous magnetic fields generated by electric power stations and other similar sources of magnetic fields. Site selection for installing such equipment therefore needs to be carried out with caution. Many agencies have rated the general performance of this equipment as satisfactory.

The price of a Hi-Star Volume Counter/Classifier, from a product catalogue, is $975. This includes a battery charger. Also, the price of the accompanying portable data management software, HDM-90, is $950. The Hi-Star portable 486 Laptop Computer is priced at $2,995, while the mounting straps and protective cover cost $60 and $175 respectively.

4. *The Remote Traffic Microwave Sensor (RTMS), by Electronic Integrated Systems (EIS), Ontario, Canada*

The RTMS is described by its product catalog as a versatile, quick-deployment, low-cost, self-contained, and advanced sensor for detecting and monitoring road traffic at intersections and roadways. This single compact pole-mounted unit provides per-lane presence indication as well as volume, occupancy, and speed information in up to eight lanes or user-definable detection zones. From direct correspondence with the manufacturer, it has been learned that the RTMS can now carry out classification by vehicle length. The 5-lb RTMS unit is encased in a rugged water-tight box. It is mounted on a universal bracket, for securing the unit to existing poles, tilting in both axes, and quick locking. It has a installation/replacement time of 15-20 minutes. RTMS operates on the principle of a tiny radar that operates at a microwave frequency. The RTMS field of view covers a range of 10-200 ft, and a zone width of up to 30 ft. Thus, like the video detectors, radar detectors have the advantage of multiple-lane detection from a single unit. RTMS is capable of battery operation up to 1 week, and has options of solar generator/chargers. It is capable of protecting data in the event of power failure. RTMS has a user-friendly Laptop PC setup program and facilitates data retrieval using laptop or modem. It uses a standard raw data file format (ASCII), and has MS Excel analysis and report software.

RTMS has been tested extensively at several locations world-wide, including Germany, Canada and the USA. It is currently being used at several locations in these countries, and in the Far East. In a non-intrusive technology study carried out by Minnesota DOT, FHWA and SRF Consulting, in May 1997, RTMS was noted for its good performance in inclement weather, ability to detect stopped vehicles, and capability of operating in side-looking mode to service multiple lanes. In the conclusions of a report on a demonstration project for RTMS by the Ontario Ministry of Transportation, it was stated that an RTMS system utilizing wireless communications can be installed for about one-fifth the cost of conventional loop detectors, and that "...the operation of the RTMS units proved reliable". RTMS-based freeway management projects include the Milwaukee FTMS, ARTIMIS Cincinnati OH, the Lantau Fixed Crossing in Hong Kong, the I-10 Santa Monica Freeway in Los Angeles, and the I-93 Boston Central Artery Mainline Tunnel.

Tests carried out by the New York City DOT in 1995 concluded that the microwave radar systems can collect necessary traffic data with an accuracy comparable to the existing loop detectors, and that previous tests carried out by other agencies such as the Texas DOT (Austin) support this conclusion. The report states that about 50 additional microwave sensors will be in operation in the New York City Area in the near future. The Minnesota, Ontario and New York tests pertained to traffic volumes, and it may be necessary for INDOT to confirm the efficacy of this equipment for vehicle classification before making any decision to invest in it.

The prices (in US dollars) of RTMS and its accessories as of April 1, 1997, are shown below:

Description	Quantity	Price
1. RTMS unit Model X2 including bracket and back connectors		$3,300
2. Set-up program + Demo software and User Manual		free
3. On-site 1-day training (Mandatory with first time purchase)		$1,500
4. 30ft. long, 6-zone connectorized RTMS X2 cable		$200
5. Counter Unit and Setup + Analysis software		$450
6. RTCP Counting package (Includes RTMS ModelX2, Counter Unit, Junction Box, cable, set-up and Analysis software)		$4,000
7. Additional brackets		$50
8. Additional Back Connectors (including back-shell)		$80
TOTAL		$9580

6. *Traffic Data Acquisition Passive Infrared (PIR) Detectors IR 250, by Advanced Sensing of Infrared Motion (ASIM) Engineering Ltd., Switzerland.*
The detectors of the IR 250 series are designed for vehicle presence, counting, occupancy, speed assessment and vehicle length classification. Particular advantages of this system are the capability to operate with extremely low power consumption and a two-way data communication in order to operate several individual detectors with one data collection module. The detectors can be mounted not only directly above the lane to be observed but also on a pole at the side of the lane.
In a non-intrusive technology study carried out by Minnesota DOT, FHWA and SRF Consulting, in May 1997, the ASIM Infrared passive detector was found to be the only device to excel at collecting volume data at both freeway and intersection test sites.

7. *Dual Technology (Passive Infrared/Doppler Radar) Detector DT 280, by Advanced Sensing of Infrared Motion (ASIM) Engineering Ltd., Switzerland*
The detectors of the DT 280 series are designed for vehicle counting, occupancy measurement, speed assessment, and vehicle length classification using a combination of Passive Infrared (PIR) and Doppler Radar. They are based on the same approach as the IR 250 series but involve the addition of a K-band Doppler Radar for increased accuracy of speed measurement and for the capability of full self calibration. This equipment, like the IR250, can be mounted on a pole or on an overhead beam.

Equipment that uses advanced "non-intrusive" technologies have been commercially available for almost a decade. However, many traffic engineers have viewed such equipment with what can be described as "cautious admiration". This is probably because stated capabilities of such equipment, trumpeted by manufacturers in various adverts and articles, had not been confirmed by independent assessment of the uses and limitations of such equipment. Therefore, engineers were apprehensive at investing resources in this rather relatively expensive new equipment. In the past few years, however, there have been a number of field studies carried out by government agencies, private organizations, and academia that have thrown light on the performance and capabilities various types of non-intrusive traffic detection technologies. Descriptions of some of these tests are provided below:

1. *The FHWA/Hughes Aircraft test (1993/1994* (ref: *FHWA/Hughes Field Test of Non-Intrusive Traffic Detection Technologies*): The Hughes study tested about 20 different devices (using 12 different technologies) at eight different locations in three geographically-diverse areas, and under various weather and traffic conditions for both freeway and surface street applications. The objective of this test was to investigate the sufficiency of current non-intrusive traffic data collection technologies for ITS applications. The study showed that the video image processor and laser radar were capable of effectively monitoring vehicle classification by length, while laser radar was capable of classification by profile as well. The video image processor models tested were (i). Autoscope 2003, by Econolite, (ii) TAS by Computer Recognition Systems, (iii) Marksman C-CATS 810 by Golden River Traffic, (iv) IDET 100 by Sumitomo, and (v)

Model 2000 by EVA. The laser and true presence radar systems were (i) 780D1000 by Schwartz Electro-Optics, and (ii) RTMS by Electronic Integrated Systems.

2. *The FHWA/SRF Consulting Group/Minnesota DOT test (1995/1997)*: (ref: *Field Test of Non-Intrusive Traffic Detection Technologies*, presented at NATDAC '96 by Polk, Kranig, and Minge): Phase I of this study, which ended in January 1996, evaluated 10 devices that use non-intrusive technologies such as infrared, magnetic, radar, microwave, acoustic, ultrasonic, and video. The purpose of the study was to evaluate the performance of the various devices in collecting historical traffic data at temporary locations in urban areas. At the freeway test site, most of these equipment types were found to count within 3 percent of the baseline volume data, while the passive infrared device (model IR224 by ASIM Engineering Ltd.) was slightly more accurate than the rest at the intersection test site. Video and radar devices were found to have the advantage of multiple lane detection from a single unit. Overall weather and heavy traffic conditions were found to have minimal effect on most of the equipment tested, with the exception of the magnetic probes installed under the pavement, whose cables became brittle and split up at very low temperatures. Also, salt spray generated by the traffic stream coated equipment with a layer of grime and impacted the performance of some video devices. Furthermore, changing lighting conditions during dusk and dawn were found to affect some of the video devices. It was found that extensive installation work is required to use video and passive magnetic devices, making them relatively unsuitable for temporary data collection. A paper written by Polk, Kranig and Minge on this test and presented at NATDAC '95, remarks in its conclusion that the pulse ultrasonic, Doppler microwave, and radar equipment worked relatively well under varying environmental and traffic conditions, and that these equipment types are relatively easy to install and calibrate, and to receive data from, and are cost effective. This test primarily covered volume-counting capabilities of the equipment, and thus precluded extensive classification analysis of equipment capabilities. The test report states that it was possible to perform satisfactory classification analysis on freeway data from the active infrared and video devices, and the radar device provides an approximate two-level classification scheme. In the second phase of this test (slated to begin February 1996) it was intended to analyze vehicle classification capabilities more extensively.

This report stated that the differences in performance from one device to another were found to be more significant than the differences from one technology to another, and recommends that it is more important to select a well designed and highly reliable product than to narrow selection to a particular technology. The report also cautions that several factors need to be considered in selecting a device for a particular application. These factors include (i) level of expertise and time spent for installation, calibration and removal, (ii) capability to monitor multiple lanes, if required, (iii) desired flexibility in mounting location, (iv) availability of wireless communication technology to simplify data retrieval, (v) availability of personnel for needed maintenance, and (vi) any need for simultaneous monitoring of more than one count type. As a result, the report refrained from clearly identifying a single device or technology as being the best.

3. *The Bolt, Bernenek and Newman, Inc., (BBN) study*: (ref: *Field Test of Non-Intrusive Traffic Detection Technologies*, presented at NATDAC '96 by Polk, Kranig, and Minge): BBN carried out a field test to compare the capabilities of infrared, sonic, ultrasonic, microwave, and video detectors. This study utilized equipment that were developed exclusively for the test, and a data acquisition system was specifically developed to receive data from the various equipment. The BBN test concluded that the best candidate to inexpensively replace traditional magnetic loop detectors to provide vehicle presence, speed, and classification is a combination of pulse ultrasonic and either doppler ultrasonic or doppler microwave.

4. *Other tests*: Several agencies, academic institutions and private concerns have carried (or are carrying out) out non-intrusive equipment tests of varying scopes and objectives. The Autoscope 2003 video sensor, manufactured by Econolite, has been tested by the University of Nebraska. The ability of ultrasonic devices to obtain intersection turning movements has been investigated by Ohio University, and the Texas Transportation Institute has evaluated the capabilities of infrared and ultrasonic traffic detection equipment. A field test to assess the ability of ultrasonic devices was carried out by the University of California at Berkeley. The Heusch Boesfeldt Engineering company tested a model K1 RTMS unit on an Autobahn No. 4 in Aachen, Germany. The Center for Transportation Research at Virginia Polytechnic University has a continuous program that evaluates the effectiveness of traffic detection technologies. The Ontario Ministry of Transportation carried out three separate tests in 1991/1992 on a heavily traveled 7-lane highway in Toronto (the Don Valley Parkway), in a continuous test chamber, and at Centralia airport facility to evaluate the performance of the RTMS radar detector. There are indications that INDOT and Purdue University have carried out some tests on such equipment at sections of the Borman Expressway, but to date no documentation on these tests have been obtained.

Conclusion

Classification and volume data at urban areas are useful to the Congestion Management System, Metropolitan Planning Organizations, and other end-users. The current loop system has several limitations at multi-lane and congested sites, and it is suggested that some of this equipment that use non-intrusive technologies be procured to address these peculiar problems at sites of interest to INDOT's CMS. Based on a study of the capabilities of the various equipment described above, the results of the field tests carried out by various agencies, and the unique requirements of INDOT, the procurement and installation of the following equipment for use by INDOT, are recommended:

a) Autoscope video sensor, manufactured by Econolite/Imaging Sensing Systems
b) RTMS, manufactured by Electronic Integrated Systems

It is to be noted, however, that there are constantly on-going research and developments in the use of non-intrusive technologies for traffic monitoring. Current non-intrusive equipment can only classify vehicles by vehicle length and not by axle configuration. Furthermore, classification is done for only a few classes which must be defined by the

user based on vehicle lengths. As such, only a few of the recommended equipment should be purchased for experimental use.

A typical non-intrusive traffic monitoring equipment package consists of the following components: a mounted unit at the site, a central processor (may include a monitor) usually stationed at the main office of the data collection agency, and appropriate computer software and hardware for analysis of collected data.

As an experimental measure, the equipment may be used at a number of selected sites. For Autoscope, depending on the number of cameras per site (usually a set of 4), capability of the cameras (i.e., closed-circuit vs. on-site recording) and the nature of the video detection algorithms that seem appropriate, the purchase price is expected to fall within a range of $15,000 - $30,000. For RTMS, a set of 2 units, needed to monitor a typical intersection, will cost about $17,000. For each technology, a set should be mounted at a selected intersection of interest for about 4 weeks before being moved to another site. Use of this equipment may be shared among the sites of interest on a scheduled basis.

Traffic monitoring equipment of this sort has great potential for use in other data collection of surveillance activities, such as investigation of the impact of traffic control measures, studying traffic flow patterns in construction zones and other special traffic areas, and investigating the events that precede occurrence of traffic conflicts and crashes at accident-prone areas for the Safety Management System. Also, monitoring of vehicle classification on multi-lane and congested sections of National Highway System segments, such as I-465, can be carried out using this equipment.

Such a program, at its experimental stage, would require the following resources:

- Employment of (i) 2 field staff with prior training and experience in installation and maintenance of such equipment (ii) 1 office-based staff whose duty will be to monitor and analyze incoming data using appropriate software back at the head office, and to generate periodic (e.g., daily and weekly) reports.
- A light truck for conveying the equipment from one site to another.
- A personal computer. No additional software will be needed for these systems because relevant software for data processing and analysis is part of the package for both types of systems.

The field crew responsible for the periodic installation and re-deployment of non-intrusive units may be given the additional responsibility of other duties such as calibrating equipment at ATR and WIM stations. This is because non-intrusive units are left to operate independently until the scheduled times of removal and personnel responsible for this activity are expected to have plenty available time between such visits.

APPENDIX B3-1

TRAFFIC DATA COLLECTION REQUEST

Indiana Department of Transportation
Roadway Management Division

<table>
<tr><td colspan="2">A. Request Details:
1. Submitted by:
2. Use of data:
3. Date of Request:
4. Last date for receipt of data:
5. Request number:
6. Other request details:</td></tr>
<tr><td>B. Site Details:
1. Site description:

2. Terminal points of site:

3. County/City/Sector:

4. Other site details:</td><td>5. Sketch of site (if necessary):</td></tr>
<tr><td colspan="2">c. Details of Required data:
1. Count Type:

2. Further details of Count type:

3. Desired period (if any) for data collection:
4. Duration:
5. Frequency:
6. Other details:</td></tr>
<tr><td colspan="2">General Remarks:</td></tr>
</table>

This form is based on that provided on p. 23 of the AASHTO Guidelines for Traffic Data Programs

DRAFT TMS/H Data Action Plan **B4**
Highway Safety Management System (SMS)
Samuel Labi and Jon D. Fricker
September 21, 1998

INDOT Contact Person:
John Nagle, Roadway Management Division, GCN808, 317-232-5464, FAX317-232-5478.

INDOT Work Plan Activity: *Adequacy/ accuracy of existing data collection process to satisfy traffic data needs of the Highway Safety Management System.*

23 CFR Chapter 1, Subchapter F (Transportation and Infrastructure Management), Part 500 (Management and Monitoring Systems), Subpart D (Highway Safety Management System) Section 500.407(a), and (a)(4), *Federal Register*, 1 December 1993, p. 63480: " These plans, processes, procedures, and practices [for SMS] shall incorporate ... collection, maintenance and dissemination of data [which] shall consist of information pertaining to crashes, traffic, ... "
Also, Subpart H (Traffic Monitoring Systems for Highways), Section 500.807(b), *Federal Register*, 1 December 1993, p.63484: "Traffic Data...shall be to the statistical precision ... specified by the data users ..."

With the acceptance of the Interim Final Rule (*Federal Register*, 19 December 1996) numbering of the above-quoted sections has been changed as follows: Section 500.407 is now 500.108, and Section 500.807(b) is now 500.204(b).

A. TRAFFIC DATA NEEDS

1. **Type of data required:**
   - Traffic volumes, e.g., approach volumes, turning volumes
   - Vehicle classification (% commercial vehicles)
   - Vehicle Miles Traveled (VMT) for corridor and system level

2. **Required location of data collection sites:**
   System-level data - locations of Continuous and Coverage count sites.

   Site-specific data
   - Permanent locations: a) Specified interchanges and intersections
     b) Specific locations or road sections of interest to the Safety Management System
   - Temporary locations: a) Road construction zones
     b) Special traffic generators

At specific sites, traffic volumes and vehicle classification are needed for each lane and direction of travel.

3. **Minimum frequency and duration of data collection for site specific data:**
No specific minimum frequency and duration for site-specific data has been indicated by the Contact Person for the Safety Management System. In the event that SMS requests a special count, the frequency and duration of such a count should be accompanied by a specification of the duration and frequency.

The Highway Safety Management System (SMS) according to the *Federal Register*, in its December 1996 issue, is "a systematic process that has the goal of reducing the number and severity of traffic crashes by ensuring that all opportunities are identified, considered, implemented as appropriate, and evaluated in all phases of highway planning design, construction, maintenance and operation and by providing information for selecting and implementing effective highway safety strategies and projects". An essential component of an SMS, according to the *Federal Register*, is the collection and maintenance of data necessary for identifying problems and determining improvement needs. Traffic volumes are needed for the computation of accident rates and design of traffic control systems, while vehicle classifications are needed for determining safety conflicts due to vehicle mix and computation of accident rates per vehicle type.

The types of traffic data indicated above are needed for analysis and processing to yield statistics such as percentage of commercial vehicles (FHWA Class 4 and above), lane usage, and other factors often used in safety management.

B. INFORMATION ON THE EXISTING SITUATION

1. **Data collection equipment and sites.**
Table 1 in the Appendix shows details of the equipment that is used to collect needed traffic data for use by all elements of the State's traffic monitoring system, including the Safety Management System.

2. **Data collection personnel**
Table 2 in the Appendix shows the various personnel currently responsible for collection of data for the overall traffic monitoring system at INDOT.

C. EVALUATION OF THE EXISTING SITUATION

INDOT's Contact Person for the Safety Management System emphasizes that traffic data reported to this management system should, as much as possible, reflect current conditions.

Data on system-level AADTs and site-specific traffic volumes are currently collected under the existing Continuous (ATR) and Coverage count programs and reported to SMS. However, given the current 3-year cycle period for coverage counts, SMS may receive traffic data for a site whose most recent count may be up to three years of age. Even with the application of the necessary adjustment factors for traffic growth, such data may not reflect current traffic conditions. This problem is more readily felt in the case of site-specific data than for system-level data. This is due to the higher sensitivity of site-

specific traffic characteristics to changes in land-use patterns and trip generation patterns. It is recommended that special request counts be carried out for specific sites for which ...

a) the most recent count is more than 1 year old,
b) the most recent count is deemed too out-dated by SMS, or
c) there have been significant changes in trip-making patterns in the vicinity of the site of interest since the time of the most recent coverage count at or near that site e.g., construction of a new shopping mall.

Data collection at temporary sites and sites of specific interest to the SMS, such as road construction zones and special traffic generators, need to be carried out at the request of the SMS if the SMS decides that such areas are not sufficiently near any existing ATR or recently monitored coverage count site. The Safety Management System is expected to benefit from the purchase of non-intrusive traffic monitoring technologies such as video-detectors. Using such equipment, it may be possible to study actual pre-crash and conflict events in greater detail.

Requests by SMS for special counts should indicate the duration of monitoring. A sample form for such a request is attached in the Appendix of DAP B3.

For system-level data, INDOT's Contact Person for the Safety Management System has indicated that any frequency and duration of counts that would yield reliable estimates of AADT are acceptable. The Traffic Monitoring Guide of the FHWA provides precision levels within which system-level data may be considered reliable and statistically valid. In other sections of this study, the Continuous and Coverage count programs have been reviewed to yield reliable and statistically valid estimates of system-level traffic data. It is expected that with the implementation of those recommendations, system-level data reported to SMS would be within specified precision levels.

The entire traffic data needs of the Safety Management System cannot be fully met by the current INDOT traffic monitoring program. This is because several areas of interest to the SMS are located in urban areas, whose traffic data collection responsibilities fall under the jurisdiction of metropolitan planning organizations (MPOs). Hence effective and regular liaison between SMS and the traffic data collection divisions of MPOs is recommended, so that requisite data for the Safety Management System at these areas can be obtained from such organizations on a regular basis. Such liaison may take the form of periodic meetings, or/and delegation of the duty of monitoring traffic data collection activities carried out by the MPOs to a particular staff within the SMS. Following such a procedure would be consistent with the principles of holism and parsimony, and coordination of data collection recommended by the FHWA in the *Traffic Monitoring Guide*, and by *AASHTO Guidelines for Traffic Data Programs*.

According to the *Federal Register*, in its December 1993 issue, "data bases and data sharing shall be integrated as necessary to achieve maximum utilization of existing and new data within and among the agencies responsible for roadway, human, and vehicle elements."

DRAFT TMS/H Data Action Plan **B5**
Intermodal Management System (IMS)
Samuel Labi and Jon D. Fricker (765-494-2205, FAX 765-496-1105)
September 21, 1998

INDOT Contact Person:
Steve Smith, Planning Section, GCN901, 317-232-5646, FAX 317-232-1499.

INDOT Work Plan Activity: *Assess adequacy/accuracy of existing data collection process to satisfy the needs of the Intermodal Management System.*

23 CFR Chapter 1, Subchapter F (Transportation and Infrastructure Management), Part 500 (Management and Monitoring Systems), Subpart G (Intermodal Facilities and Systems Management System), Section 500.707, *Federal Register*, 1 December 1993, p. 63483:

(b) "... measure and evaluate the efficiency ... in moving people and goods from origin to destination."

(c) "... continuing data collection ... that is coordinated with ... congestion management, public transportation management, and traffic monitoring systems. ... Operational characteristics may include time, cost, capacity, and usage. ... obtained, to the extent possible, from the ongoing metropolitan and statewide planning processes."

Parts of this Data Action Plan are drawn from the *Intermodal Management System* report submitted to INDOT by Booz-Allen and Hamilton Inc. dated 28 February 1997. In this DAP, the report will be referred to as the BAH report.

A. TRAFFIC DATA NEEDS

1. Type of traffic data required

1.1 Demand
- Average Daily Traffic (ADT)
- Truck Demand (Average daily truck traffic)
- Peak hour volumes
- Vehicle Occupancy

1.2 Speed
- Free Flow Speed
- Congested Speed

1.3 Safety
- Accident rates per VMT
- Total accidents

Traffic data for other modes (rail, air, sea, etc.) are required by the IMS. However, this study concerns only highway traffic data. Vehicle occupancy has been addressed in Data Action Plan E of this study, while speed data needs should be addressed in a separate

study. Data for peak hour volumes and accidents could be obtained on a regular basis from the CMS and SMS respectively. Data on vehicle classification are needed to generate truck demand.

Traffic data are needed by IMS not only for identifying which intermodal facilities and links qualify for inclusion in the state's IMS, but also for sustained monitoring of the performance of such selected intermodal facilities and links. According to the BAH report (page 4-1), performance measures form the backbone of the IMS in that they are at the center of the overall processes of identifying transportation deficiencies, ranking the deficiencies and therefore forming a basis for remedial action. Performance measures suggested by the BAH report include safety (accident rate, severity distribution and cost), lost travel time (total hours per peak hour lost due to congestion), and environmental considerations (amount of fuel consumed and pollution), based on number of trips generated by the facility.

2. **Required location of data collection sites:**

2.1 Criteria for selection of existing intermodal facilities for IMS network.

The Indiana IMS has as one of its principal elements a *Network of Statewide Significance* (NSS). Using the National Highway System (NHS) within Indiana as the starting point, a collection of transportation links and facilities was assembled to form the NSS. Among the criteria used to identify links and facilities for inclusion in the NSS were the following highway-oriented criteria, BAH report page 2-3:

Table B5.1

Facility Type	Criterion
Ports	100 trucks per day in each direction
Airports (freight)	100 trucks per day in each direction
Truck/Rail Intermodal	100 trucks per day in each direction

It is implied from the above table that intermodal facilities that do not meet the above criteria are not considered "major" intermodal facilities, and are thus excluded from IMS's Network of Statewide Significance. However, IMS should request intermodal facility personnel to monitor traffic on such facilities and notify IMS when the appropriate criterion appears to have been met.

2.2 Monitoring of selected intermodal facilities

The NSS includes *access links* that connect major network elements to specialized facilities that are critical components of the intermodal transportation network. The following table (BAH report page 2-18) summarizes the data needed for these access links and possible sources of the data.

Table B5.2

Data	Possible Sources
Average Daily Traffic	MPO and INDOT, Operators of the Intermodal Facility
Truck Demand	Operators of the Intermodal Facility
Peak Hour Volumes	INDOT Congestion Management System
Vehicle Occupancy	MPOs and crash data records
Free-flow Speed	MPOs, and Operators of the Intermodal Facility
Congested Speed	MPOs, and Operators of the Intermodal Facility

- System-level data on traffic volumes and percent trucks (commercial vehicles) that are of interest to the IMS are derived from data collected at locations dictated by INDOT's ongoing Continuous and Coverage Count programs.
- Site-specific data on volumes, occupancy and speeds for the IMS are needed at permanent locations of interest such as (a) selected intermodal facility locations, and (b) specified road segments of interest to the IMS, such as connectors that link selected intermodal facilities to NHS roads. At each data collection site, data are needed for each lane and direction of travel. Site-specific traffic data at such locations may be obtained from any of the following sources:
  - continuous count sites (ATRs) that are sufficiently close to the intermodal facility or access link to collect data that are adequately representative,
  - coverage sites that are located sufficiently close to the sites of interest to the IMS,
  - MPO count sites at or near sites of interest,
  - operators of the intermodal facility

  In the event that appropriate traffic data for a particular site are not available from any of these sources, operators of the IMS should make a request to INDOT's Traffic Statistics Unit for special counts to be conducted. This request may be made either electronically or on paper. The recommended form is provided as Appendix B5.2.

A map of the State of Indiana showing the locations of major intermodal facilities is shown as Appendix B5.3. This map represents the approved NHS network in the State of Indiana, submitted by FWHA to INDOT on November 13, 1995. Also, maps showing locations of various major intermodal facilities in the state of Indiana, taken from the BAH report, are provided as Appendices B5.4(a) and B5.4(b), and B5.5(a) to B5.5(m).

3. **Minimum frequency and duration of data collection for site-specific data:**
Table B5.1 specifies the criterion (number of trucks per day) for selecting a particular intermodal facility site or road link for the IMS's Network of National Significance (NSS). However, no specific minimum frequency and duration of requisite traffic data has been indicated by the IMS Contact Person for traffic monitoring of such sites and links *after they have been selected.*

The *Federal Register*, in its December 1993 issue, defines an IMS as "a systematic process of identifying key linkages between one or more modes of transportation, where the performance or use of one mode will affect another, defining strategies for improving the effectiveness of these modal interactions, and evaluation and implementation of these strategies to enhance the overall performance of the transportation system". This document also defines an Intermodal System as a transportation network consisting of public and private infrastructure for moving people and goods, using various combinations of transportation modes.

B. INFORMATION ON THE EXISTING SITUATION

1. **Data collection equipment and sites.**
Table 1 in the Appendix shows details of the equipment that is used to collect needed traffic data for use by the Intermodal Management System, other management systems, and other elements of the State's traffic monitoring program.

2. **Data collection personnel**
Table 2 in the Appendix shows the various personnel currently responsible for collection of data for the overall traffic monitoring system at INDOT.

C. EVALUATION OF THE EXISTING SITUATION

The Intermodal Surface Transportation Efficiency Act (ISTEA), signed by the US President in 1991, signified a major shift in national transportation policy by laying more emphasis on improved intermodal transportation and mode connectivity. It was envisaged that, through an effective integration of the various transportation modes, effective and efficient and safe movement of people and goods would be enhanced.

The state's IMS network consists of the following:

- National Highway System (NHS)
- Facilities of National and Statewide Significance
- NHS Major Intermodal Connectors.

The NHS is a collection of roads selected for their strategic importance to the national economy and defense (see Appendix B5.3). NHS roads include all Interstates, some US Roads and State Roads, and a few local roads.

Facilities of National and Statewide Significance are selected for their role in the state's Intermodal System. These facilities consist of (i) passenger facilities such as Amtrak rail

stations, commuter rail stations, intercity bus stations, and passenger airports, (ii) freight facilities, such as water ports, airports, and rail/truck ports.

NHS Major Intermodal Connectors are roads that link the major intermodal facilities to the NHS.

According to the BAH report (P. C-5), the FHWA has agreed to include access links between major intermodal facilities and Interstate roadways in the National Highway System. However, no concrete documentation in this regard has been provided to the researchers of this study, hence such links will not be considered as NHS roads in this study. Secondly, if any such addition is to be made, it is recommended that access links between major intermodal facilities and NHS roads (rather than just Interstates) should be included in the NHS.

The BAH report, on page 2-19, states that “Of all [IMS's traffic data needs], ... the IMS team had best success [in data collection] with the daily and peak hour vehicle volumes. Both the INDOT Road Inventory and Congestion Management System (CMS) served the [IMS] team well as a backup source. Congested speeds proved the most challenging field to gather, particularly for the local roads. In roughly half of the cases, it simply was not available from the MPO and had to be left blank.”

Currently, the main focus of IMS highway traffic data requirements are the number and percentage of trucks in the traffic stream on road segments leading to intermodal facilities. Vehicle classification data collected for coverage counts is the most likely ongoing source of such data. The table provided as Appendix B5.1 shows the extent to which INDOT and MPO current data collection activities cover the IMS's Network of National Significance.

Access from an intermodal facility to an NHS road may consist of more than one link. For example, access from Purdue University airport (in West Lafayette) to the nearest NHS road i.e., US-231, consists of 2 links: a) SR-526, from the airport to SR-26, then b) SR-26 from SR-526 to US-231. In such cases where the access link is comprised of more than one link, it is preferred that data on both links, rather than one link, are available.

Like those of the Congestion Management System, the entire traffic data needs of the Intermodal Management System cannot be fully met by the current INDOT traffic monitoring program. This is because several intermodal facilities and road links of interest to the IMS are located in urban areas, whose traffic data collection responsibilities largely fall under the jurisdiction of metropolitan planning organizations (MPOs). Hence needed data for the Intermodal Management System at these areas need to be obtained through regular liaison with such organizations. Such efforts would be consistent with the principles of holism and parsimony, and coordination of data collection recommended by the FHWA in the *Traffic Monitoring Guide*, and by *AASHTO Guidelines for Traffic Monitoring Programs*. According to the *Federal Register*, in its December 1993 issue, “data bases and data sharing shall be integrated as necessary to

achieve maximum utilization of existing and new data within and among the agencies ...". However, the limited capabilities of MPOs in their efforts to collect traffic data must be taken into account. Most MPOs carry out only volume counts, whereas IMS seeks details on intra-zonal truck traffic in urban areas. It is therefore obvious that special vehicle classification counts may be required of INDOT by IMS. A form for such requests is found in the Appendix to DAP B3.

System-level data for the road network in the entire state are currently collected under the existing continuous (ATR) and coverage count programs. With regard to site-specific data, Appendix B5.1 shows the current scope of INDOT's traffic monitoring activities with regard to specific sites of interest (access links to intermodal facilities) to the IMS. This information was obtained from INDOT's Highway Traffic Statistics County Flow Map book, published in 1998, and the Percent Commercial Vehicles (1991-1996) document. Regarding site-specific data, the BAH report states that virtually all IMS facility [traffic data] collected during the BAH study were obtained directly from the facility owners or managers. Future traffic data collection for IMS facilities and links may be carried out in a similar fashion, because the scope of current traffic monitoring activities by INDOT and MPOs on IMS's Network of National Significance appears to be limited. In cases where facility owners do not collect the required data, and where such data are not available from ATR, coverage count or MPO count reports, special data collection requests need to be made by IMS to INDOT. A sample form for such a request is attached as Appendix B5.2.

As regards data management and reporting, the use of a relational graphic database was suggested by the BAH report. In fact, the development of a Geographical Information System (GIS) using TransCAD software was a major component of the IMS project undertaken by BAH for INDOT's IMS. This involved the development of a base map and associated routing systems (County Log Mile and Reference Post Systems) and consequent addition of layers such as Road Inventory Data, Location of Intermodal Facilities, State, US and Local access links to intermodal facilities, NHS routes, state rail network, water features, and county boundaries.

The following table, synthesized from Appendix B5.1, shows the distribution of available and required data for the various count types and for the various road categories (i.e., count locations on the State Road System and Non-State Road System).

Count Type		Total Nr. Of "counts" req'd	Available "count" data from existing programs	Number of counts that may be required by IMS
ADT	State Road System	25	25	0
	Non-State Road System	36	0	36
%CV	State Road System	25	12	13
	Non-State Road System	36	0	36
PHV	State Road System	25	0	25
	Non-State Road System	36	0	36

From the table above,
Total number of counts that may be needed on the State Road system
= 13 classification counts + 25 counts for Peak Hourly Volumes
= 38 counts

This figure is then added to the total number of special short-term counts needed annually, in Data Action Plan D1, page D1.7.

Counts on roads that are not on the state road system may be carried out by the MPOs or by the operators of the intermodal facility at the request of IMS.

APPENDIX B5.1

Current data collection activities on Access Links of the IMS network

Region	Intermodal Facility	County	Access Link(s)	ADT	% Trucks	PHV
North-western Intermodal Facilities	1. LTV Steel (Water Port)	Lake	Riley Road (Local Road)	*	*	*
	2 Plant 2 (Water Port)	Lake	Plant 2 Entrance Road (Local Road)	*	*	*
	3.. NICTD Hammond (Commuter Rail)	Lake	Hohman Street, (Local Road), and State Road 312 (State Road) Calumet Avenue	* CFM codes: Lake 3GG to 7GG	*	*
	4. Port ..	Lake	(Local Road)	*	*	*
	5. NICTD East Chicago (Commuter Rail)	Lake	NICTD Driveway (Local Road)	*	*	*
Portage Intermodal Facilities	1.Port Burn Harbor (Water Port)	Porter	State Road 249 (State Road)	CFM code: Porter 2T, 3T	*	*
	2. NICTD Dune Park (Commuter Rail)	Porter	US 12, State Road 49 (State Roads)	CFM code: Porter 9D, 1Q and 2P	Porter '94 (Sta. 0140)	*
Gary Intermodal Facilities	1. USX Corp. Port (Water Port)	Lake	Buchanan Street (Local Road)	*	*	*
	2. NICTD Gary-Metro	Lake	US-12, SR-53 (State Roads)	CFM code: Lake 2K and 2BB		
Elkhart Intermodal Facilities	1. Elkhart Municipal Airport	Elkhart	Airport Drive, Edwardsburg Highway, SR-112, SR-19 (Local and State Roads)	CFM codes: Elkhart 4Q on SR112 Elkhart 4P and 5P on SR-19	*	*
	2. Amtrak Elkhart	Elkhart	Tyler Avenue, Main Street, and US-33	CFM codes: Elkhart 8F on US-33		

ADT- Average Daily Traffic, PHV- Peak Hour Factor, CFM-County Flow Map

** - Currently, there is no evidence that this traffic data indicated is collected under existing programs, and may therefore need to be collected under a special request by IMS from one of the three stated sources.*

APPENDIX B5.1 (cont'd)

Current data collection activities on Access Links of the IMS network

Region	Intermodal Facility	County	Access Link(s)	ADT	% Trucks	PHV
South Bend Intermodal Facilities	1. Michiana Regional Center Airport	St. Joseph	Airport Drive, Old US-20 (Local Roads)	*	*	*
	2. NICTD-South Bend (Commuter Rail)	St. Joseph	Airport Drive, Old US-20 (Local Roads)	*	*	*
	3. Amtrak South Bend	St. Joseph	Bendix Drive, Old US-20 (Local Roads)	*	*	*
Fort Wayne Intermodal Facilities	1. GM Interm., Roanoke	Allen	Fogwell Parkway, Lafayette Center Road (Local Roads)	*	*	*
	2. Fort Wayne International Airport	Allen	Ferguson Road, Bluffton Road (Local Road)	*	*	*
	3.Tr/RI- NS Triple Crown	Allen	Wayne Trace, Pontiac Road (Local Road), SR-930 (State Road)	* CFM code: Allen'94 on US-30/24	* Dekalb 1992 Sta.0110	*
Waterloo/ Garrett Intermodal Facilities	1. Amtrak Waterloo	Dekalb	Lincoln Street, Center Street (Local Roads), US-6 (State Road)	CFM codes: Dekalb 4B on US-6	* Dekalb 1992 Sta.0110	*
	2. Amtrak Garrett	Dekalb	State Road 327 State Road 8	CFM codes: Dekalb 5K on SR-327 Dekalb 2F, 3F on SR-8	Dekalb 1992 Sta.0270	*
Lafayette Intermodal Facilities	1. Purdue University Airport	T'canoe	State Road 526, State Road 26	CFM codes: Tippecanoe 1X, 2X on SR 526 Tippecanoe 6M to 9M, and 1N to 4N on SR 26	*	*
	2. Amtrak Lafayette	T'canoe	Driveway of Amtrak Station into SR-26 (Also Greyhound station)		*	*

APPENDIX B5.1 (cont'd)

Current data collection activities on Access Links of the IMS network

Region	Intermodal Facility	County	Access Link(s)	ADT	% Trucks	PHV
Remington Intermodal Facilities	1. Tr/RI-Remington		Tr/TI Driveway into US-24 (Local Road)	*	*	*
Kokomo Intermodal Facilities	1. Kokomo Municipal Airport	Madison	400 North Road, 300 East Road (Local Roads)	*	*	*
	2. Anderson Municipal Airport	Madison	SR-32, from Airport to I-69 (State Road)	CFM code: Madison 3S	* Madison 1995 Sta.0640	*
Indianapolis Intermodal Facilities	1.Tr/RI- Conrail Avon Industrial	Marion/ Hendricks	US-36 (State Road)	CFM codes: Marion 1Q, 2Q, 3Q Hendricks 3Q	Marion 1996 Sta.1030	*
	2. Indianapolis International Airport	Marion	US-40 (State Road)	Marion 2S, 3S, 4S	Marion 1996 Sta.1050	*
	3. Indianapolis International Airport	Marion	Airport Expressway (Local Road)	*	*	*
	4. Eagle Creek Airport	Marion	......Blvd, 38th Street (Local Road)	*	*	*
	5. Amtrak Indianapolis and Bus Union Station	Marion	Illinois Street, South Street (Local Road)	*	*	*
Bloomington Intermodal Facilities	1. Monroe County Airport	Monroe	Kirby Road (Local Road), State Road 48	CFM Code: Monroe 4H	Monroe 1995 Sta. 0320	*
	2. Park N Ride Facility	Monroe	Dunn Street (Local Road)	*		*

ADT- Average Daily Traffic, PHV- Peak Hour Factor, CFM-County Flow Map

** - Currently, there is no evidence that this traffic data indicated is collected under existing programs, and may therefore need to be collected under a special request by IMS from one of the three stated sources.*

APPENDIX B5.1 (cont'd)

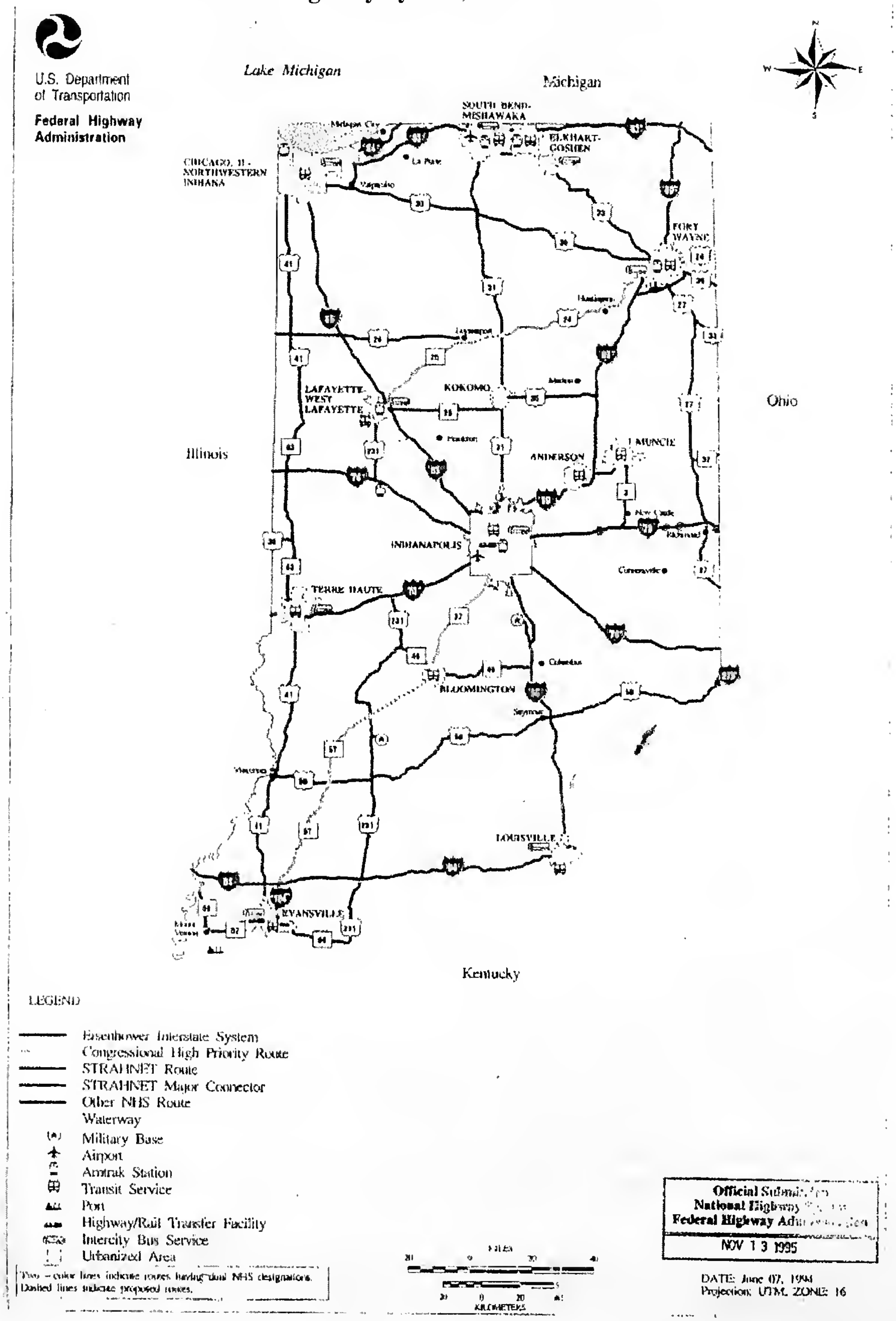
Current data collection activities on Access Links of the IMS network

Region	Intermodal Facility	County	Access Link(s)	ADT	% Trucks	PHV
Terre Haute Intermodal Facilities	1. Hulman Regional Airport	Vigo	State Road 342, State Road 42, State Road 46 (State Roads)	CFM codes: Vigo 1Q on SR-342, Vigo 1J, 2J on SR-42, Vigo 2K on SR-46	Vigo 1996: Sta.0720, Sta.0410, Sta.0420 Sta.0480	* * * *
Evansville Intermodal Facilities	1. Southwind Port (Water port)	Vanderburgh	Port Road (Local Road),	*	*	*
	2. Tr/RI Evansville (Rail)	Vanderburgh	Ray Becker Parkway	*	*	*
	3.Port Mutz (Water Port)	Vanderburgh	… Street (Local Road)	*	*	*
	4. Evansville Regional Airport	Vanderburgh	State Road 57 (State Road)	CFM code: Vanderburgh 1D	V'burg 1996: Sta.0310	*
		Warrick	State Road 662 (State Road)	Warrick 1M	*	*
	5. Port Mulzer (Water Port)					
Clark Intermodal Facilities	1. Clark International Airport	Clark	Airport Drive (Local Road),	*	*	*
			US-31 (State Road)	CFM codes: Clark 3E, 4E	Clark 1994 1996: Sta.0200	*
	2. Port Clark Maritime Center	Clark	Port Road	*	*	*

ADT- Average Daily Traffic, PHV- Peak Hour Factor, CFM-County Flow Map

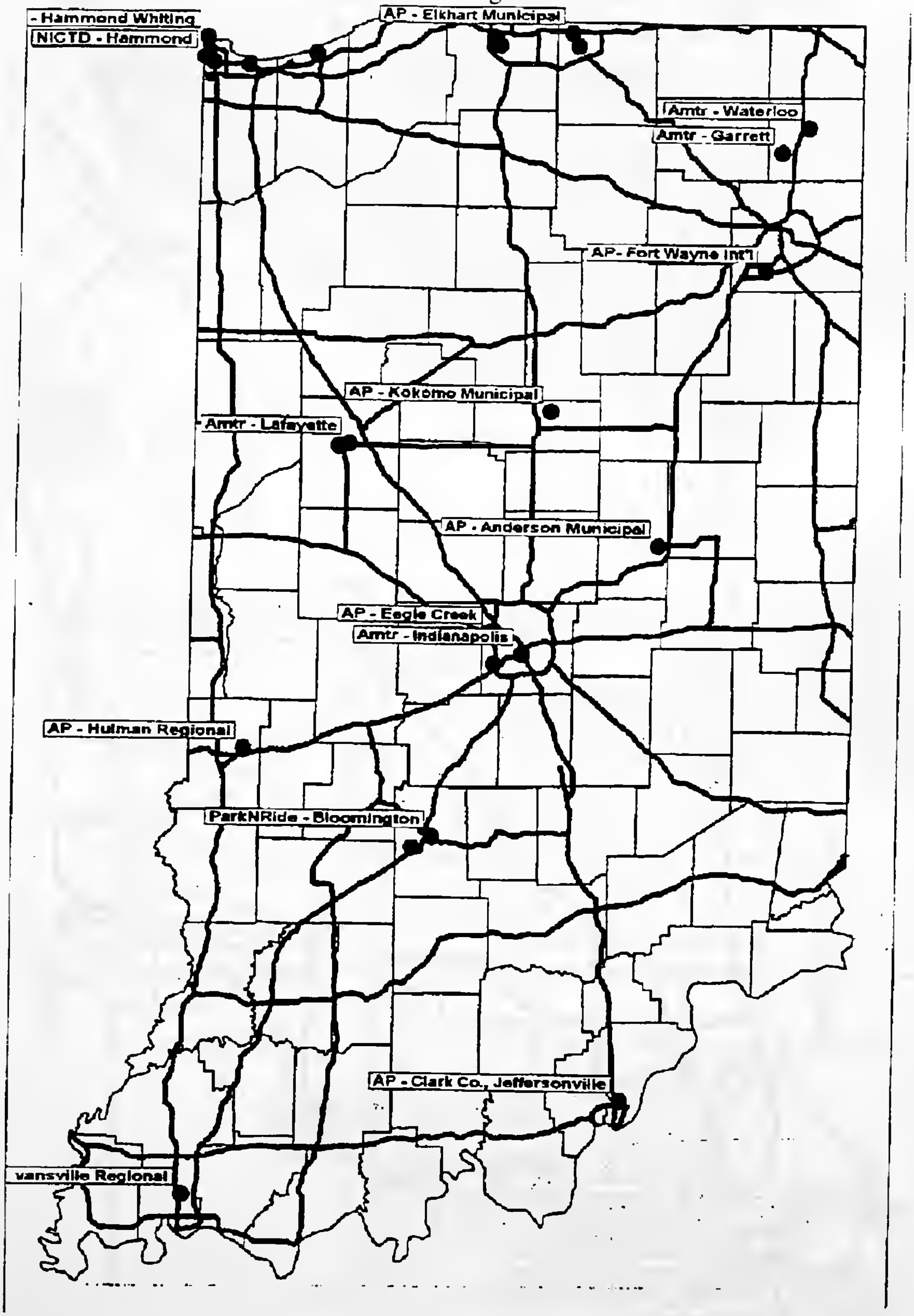
** - Currently, there is no evidence that traffic data indicated is collected under existing programs, and therefore such data need to be collected under a special request by IMS.*

APPENDIX B5.3
National Highway System, State of Indiana

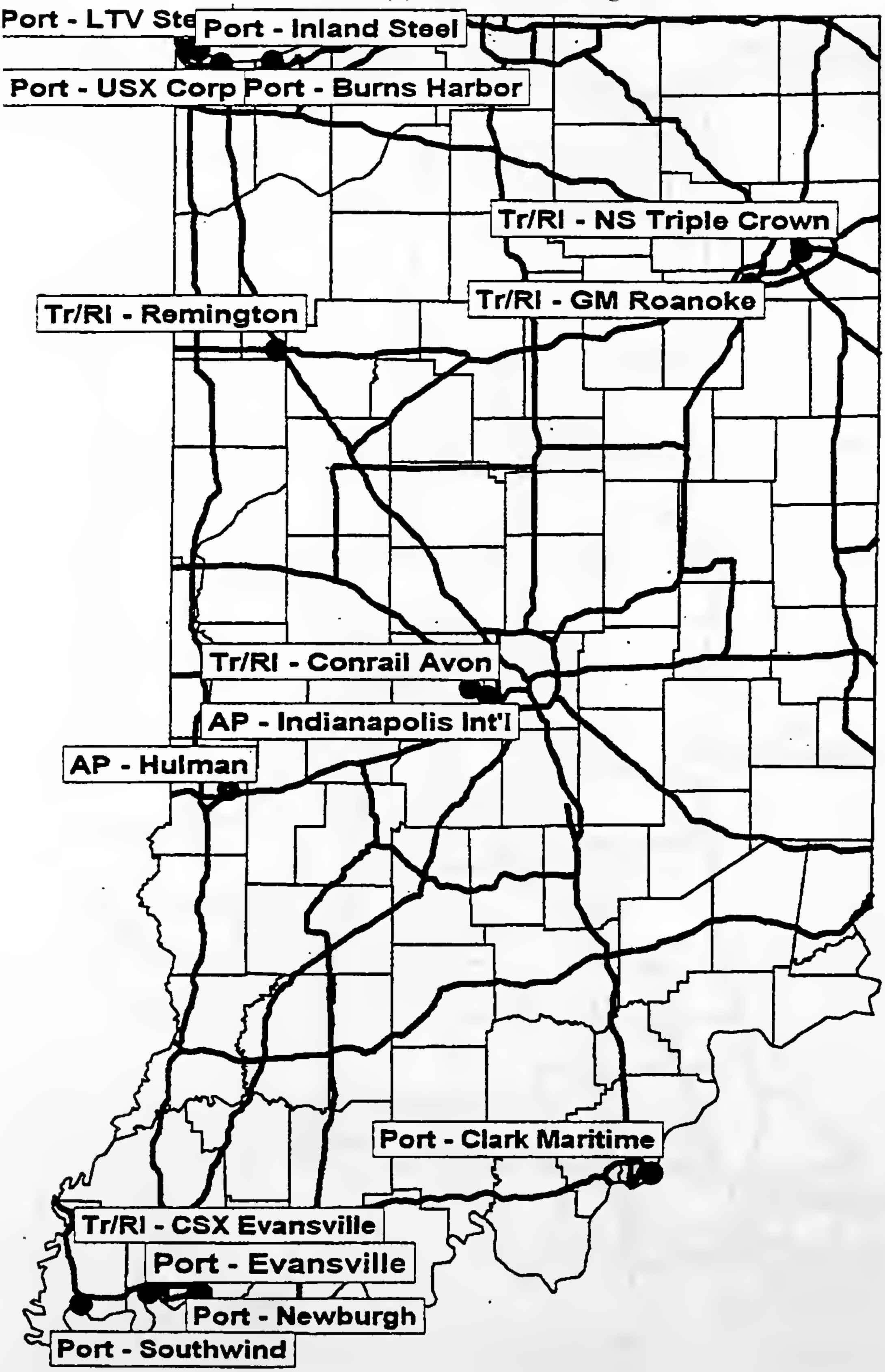


APPENDIX B5.4(a)

Intermodal Passenger Facilities

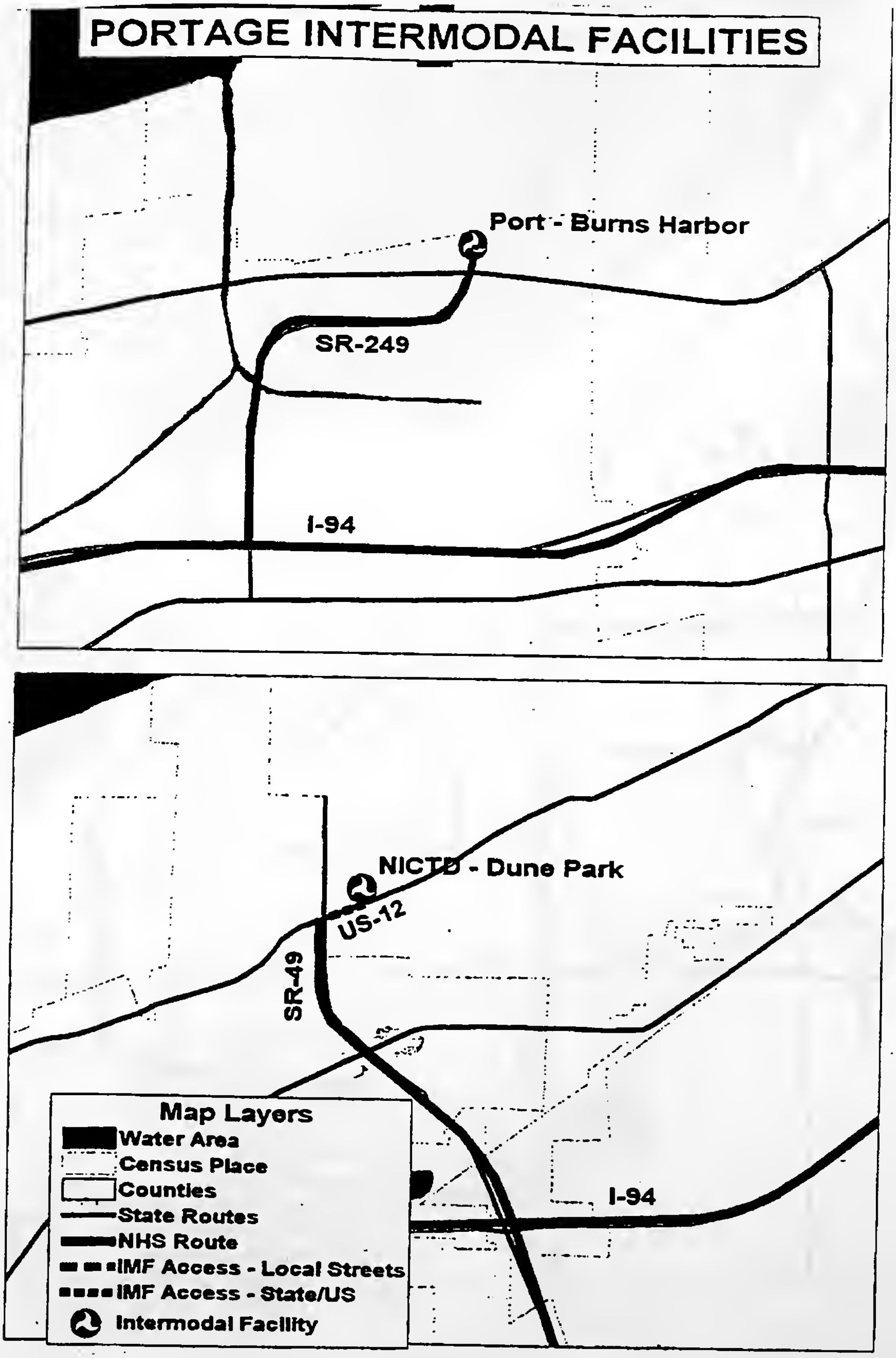


APPENDIX B5.4(b): Intermodal Freight Facilities

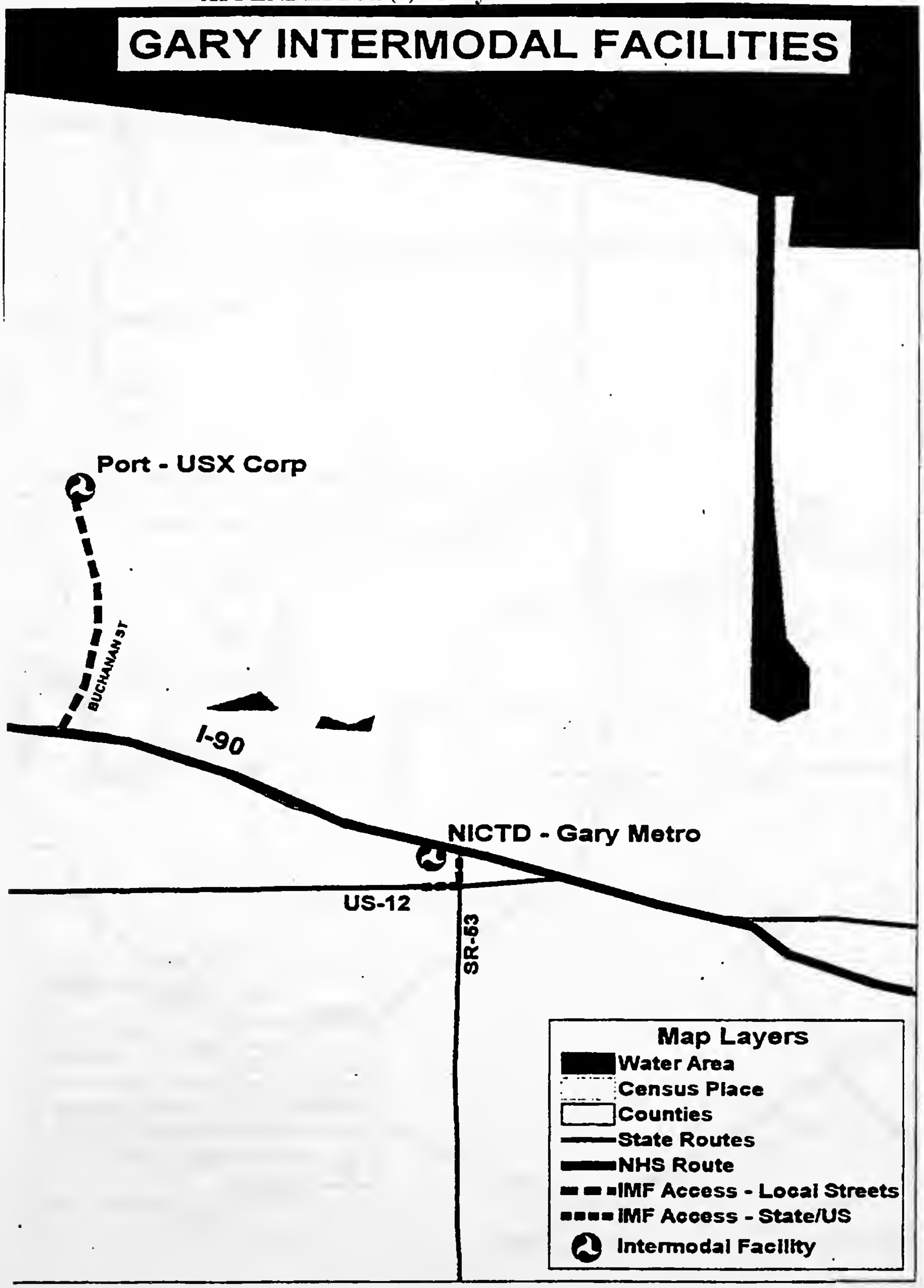


APPENDIX B5.5(a): Northwest Intermodal Facilities

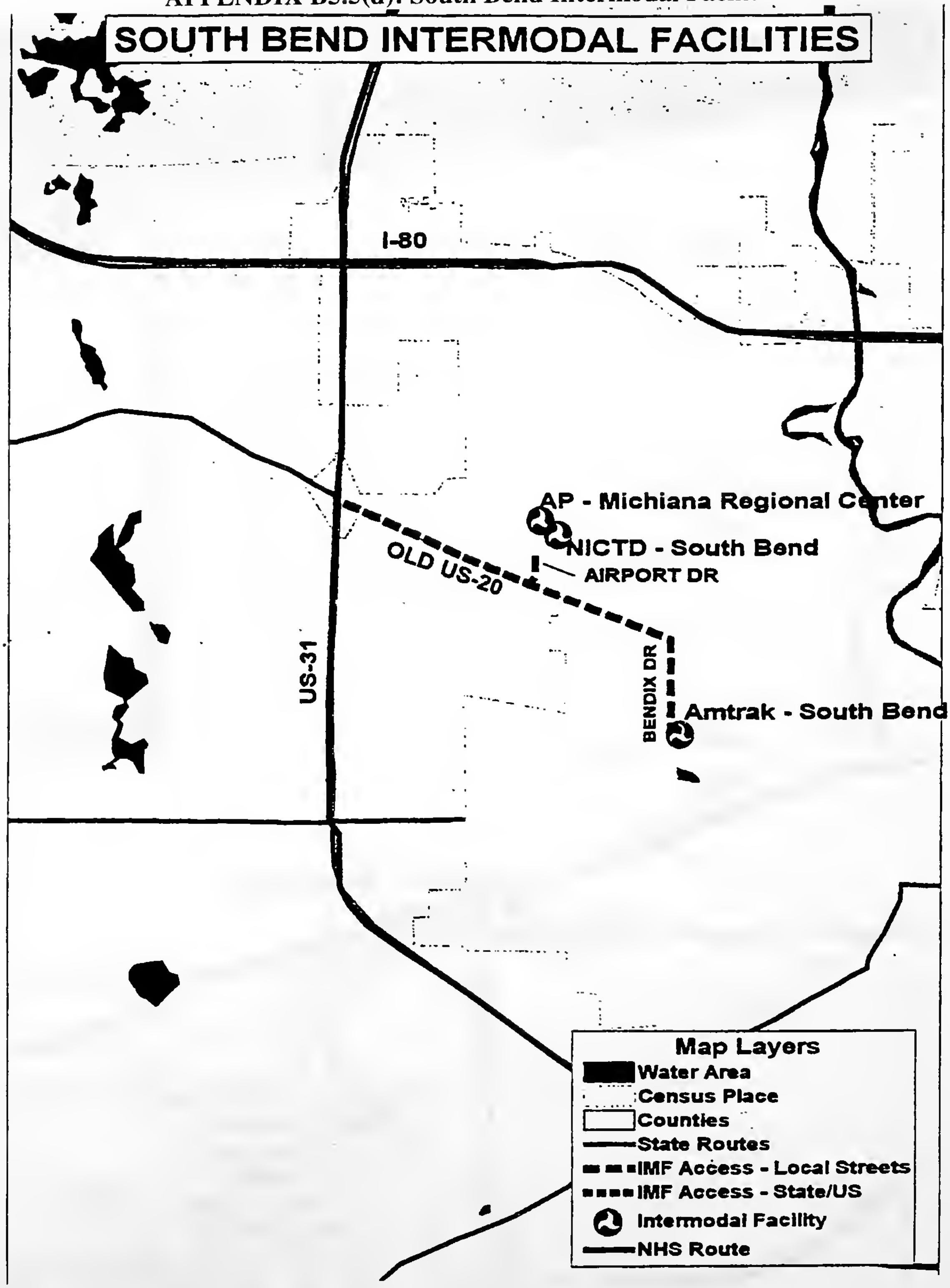
APPENDIX B5.5(b): Portage Intermodal Facilities



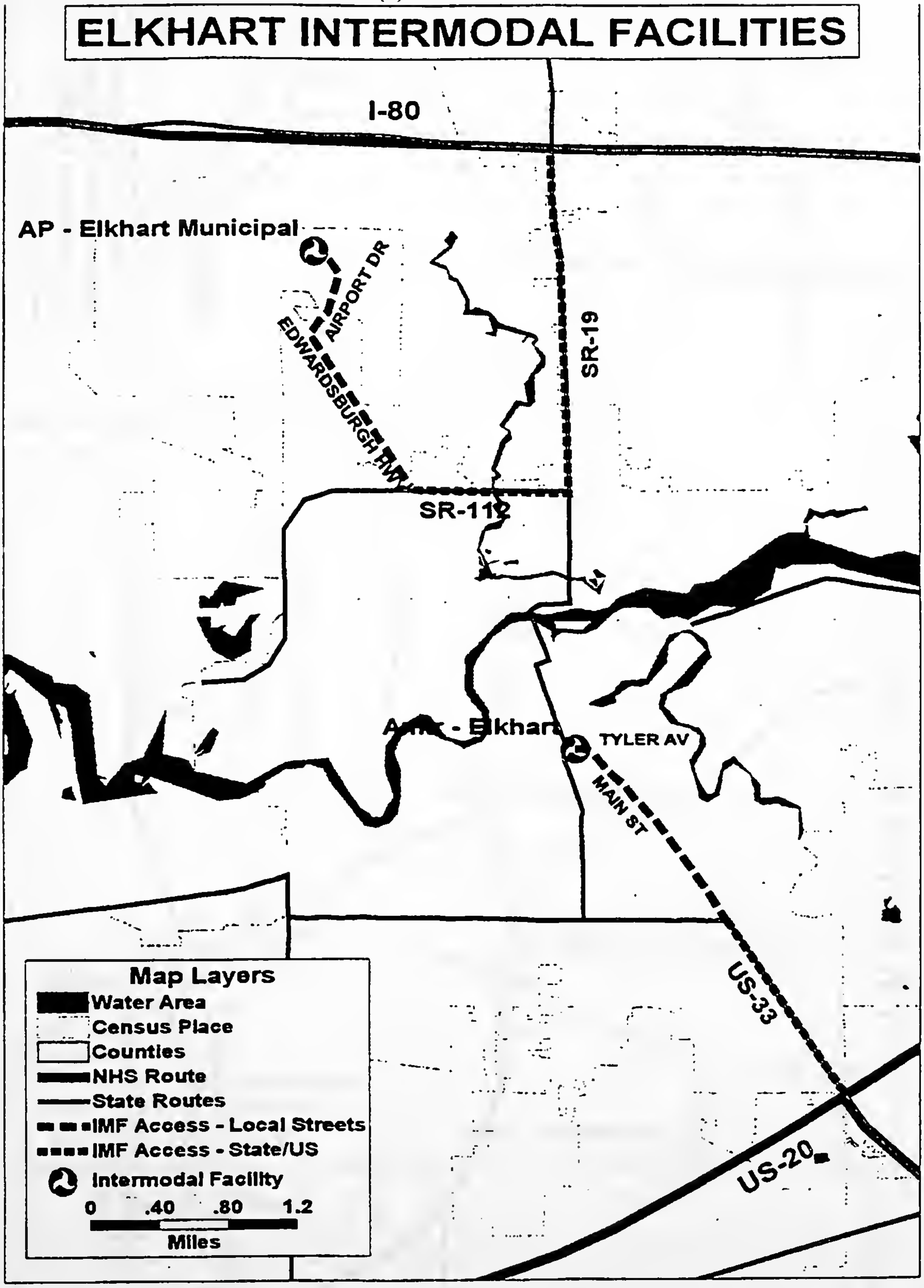
APPENDIX B5.5(c): Gary Intermodal Facilities

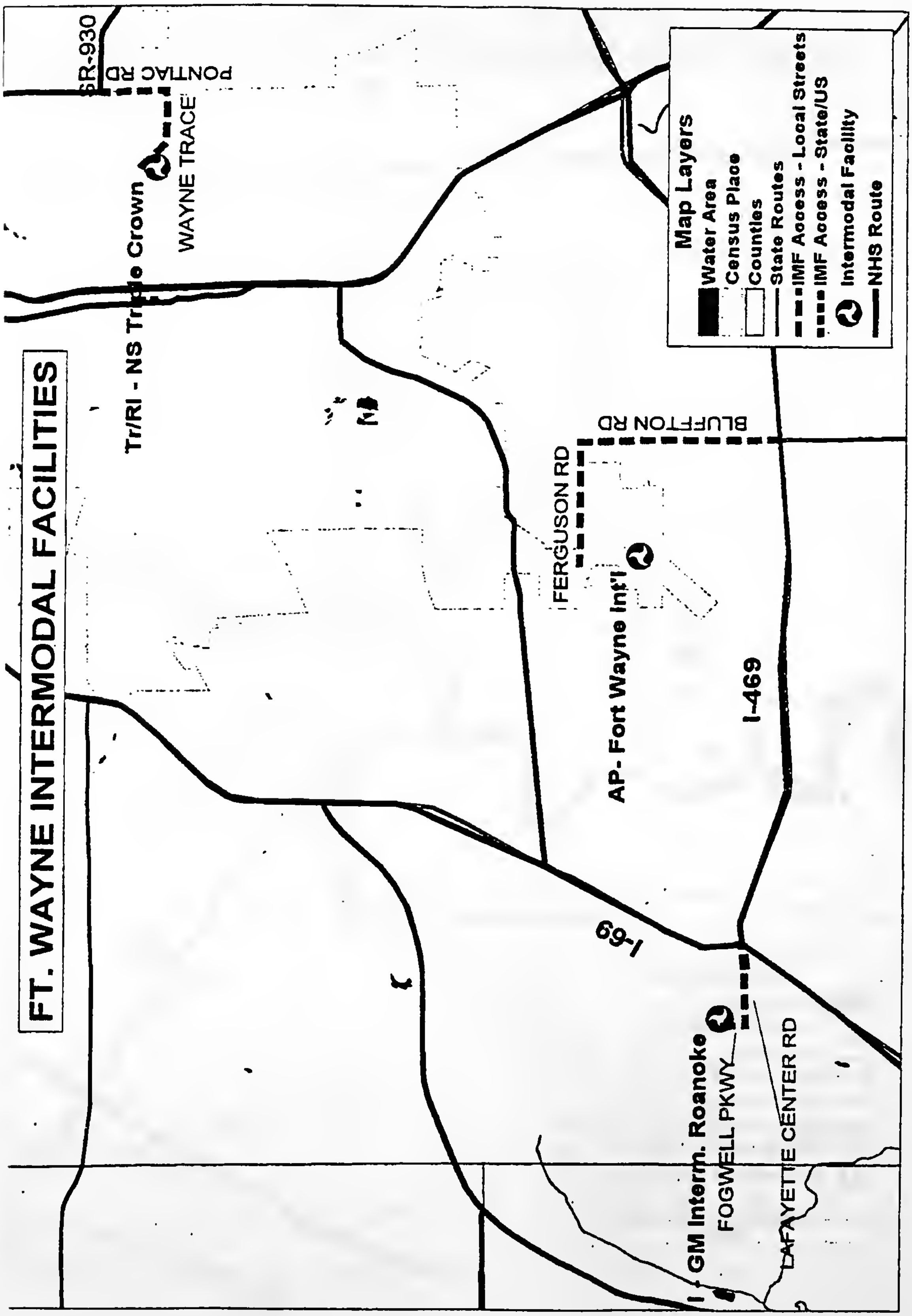


APPENDIX B5.5(d): South Bend Intermodal Facilities



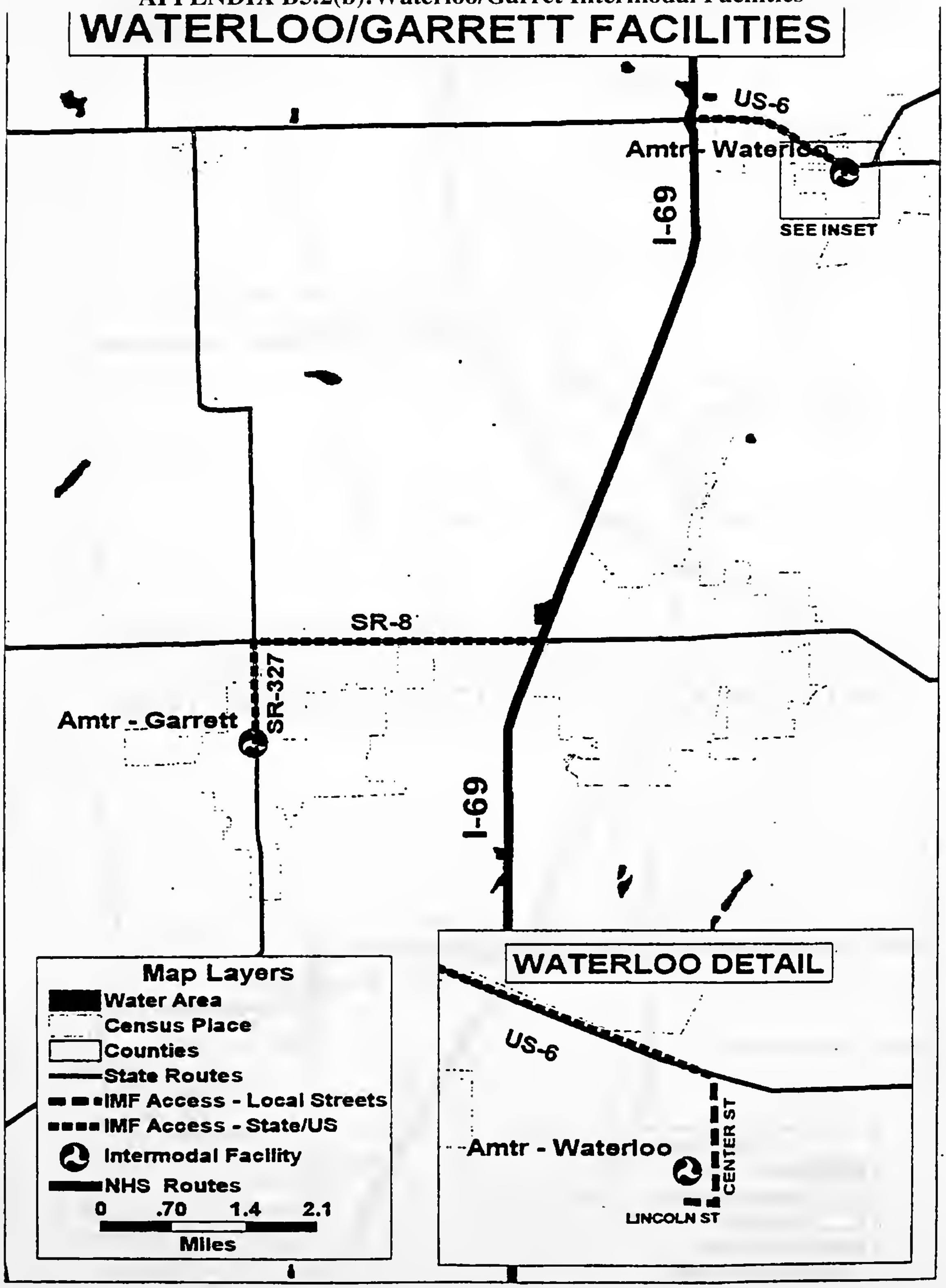
APPENDIX B5.5(e): Elkhart Intermodal Facilities

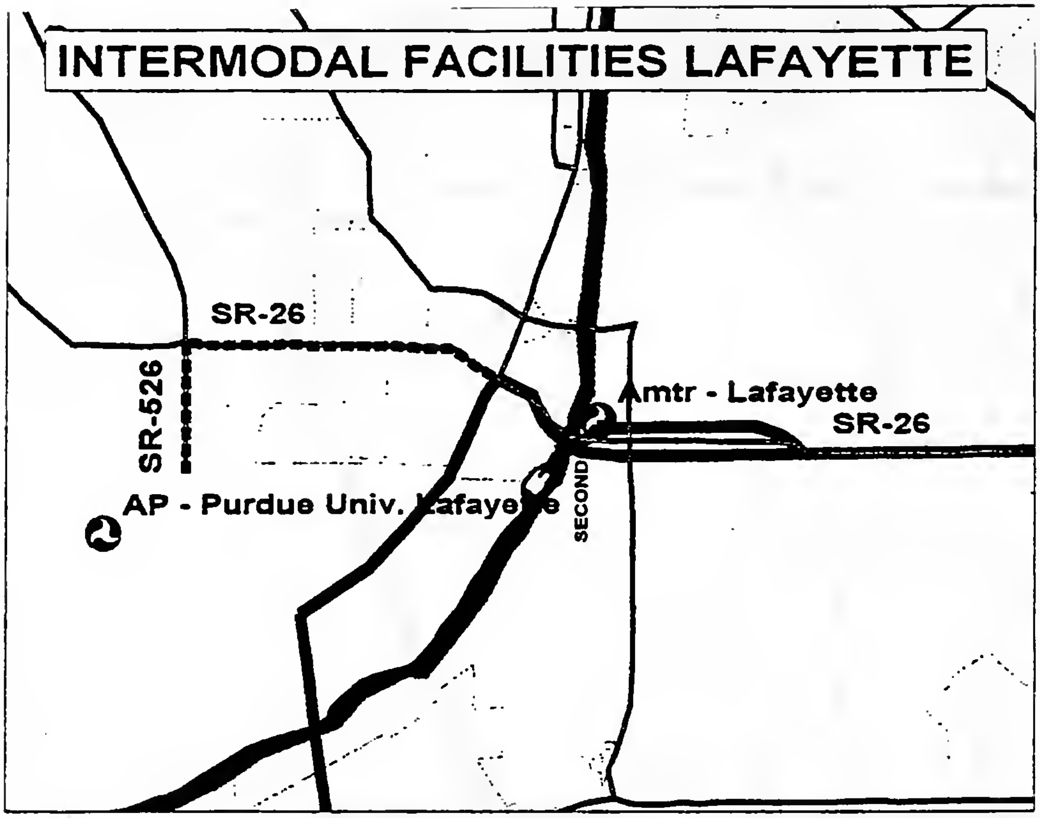


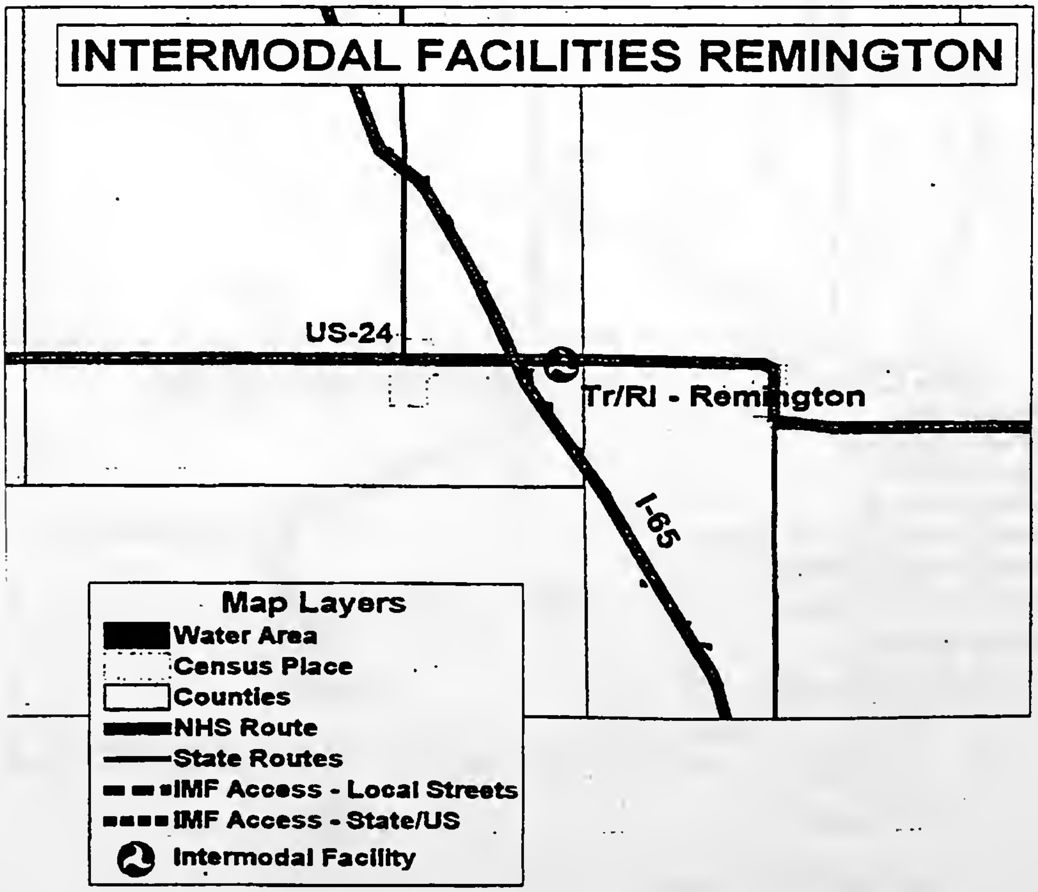


APPENDIX B5.5(f):Fort Wayne Intermodal Facilities

APPENDIX B5.2(b):Waterloo/Garret Intermodal Facilities

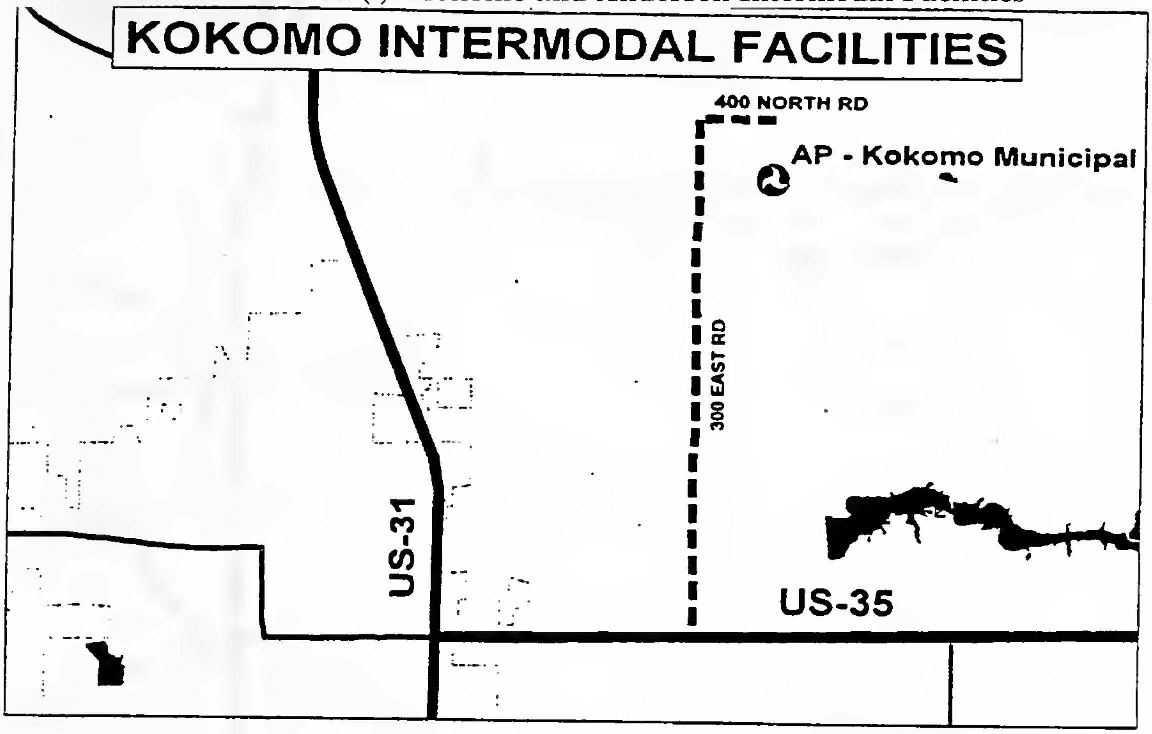


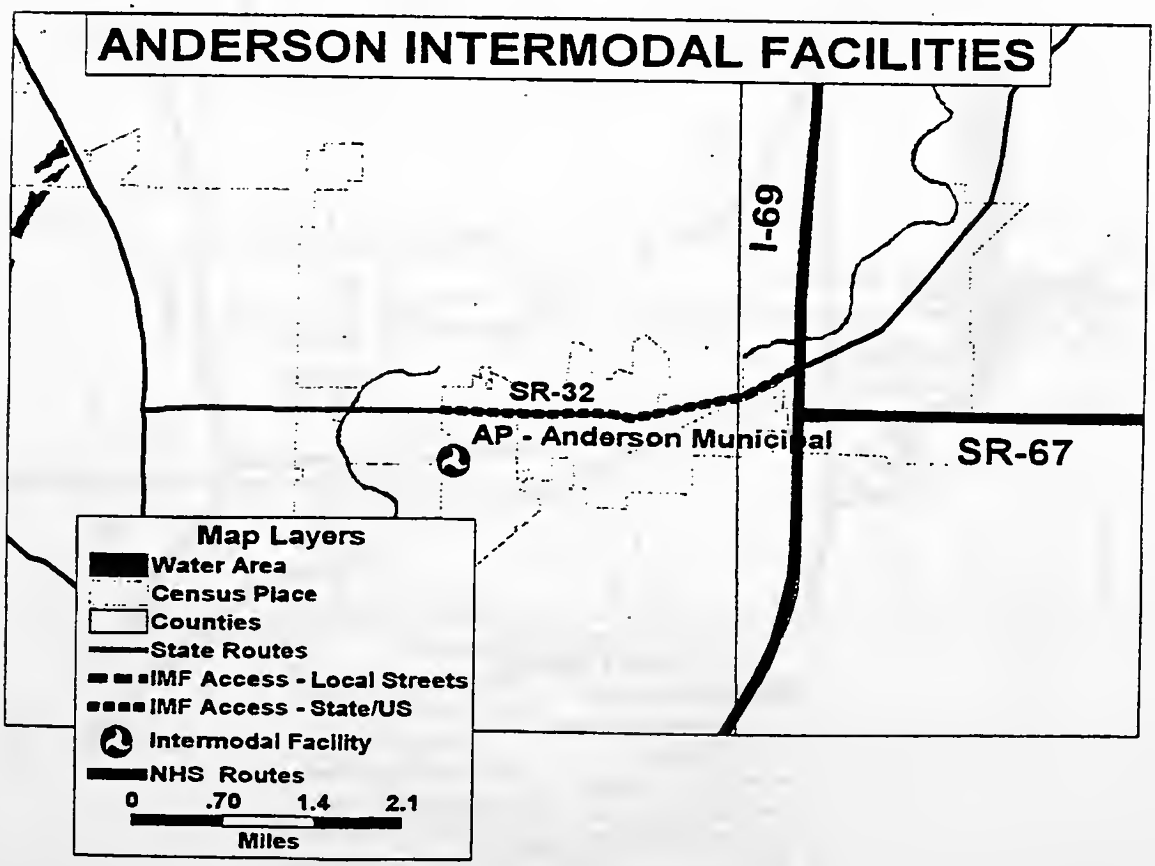




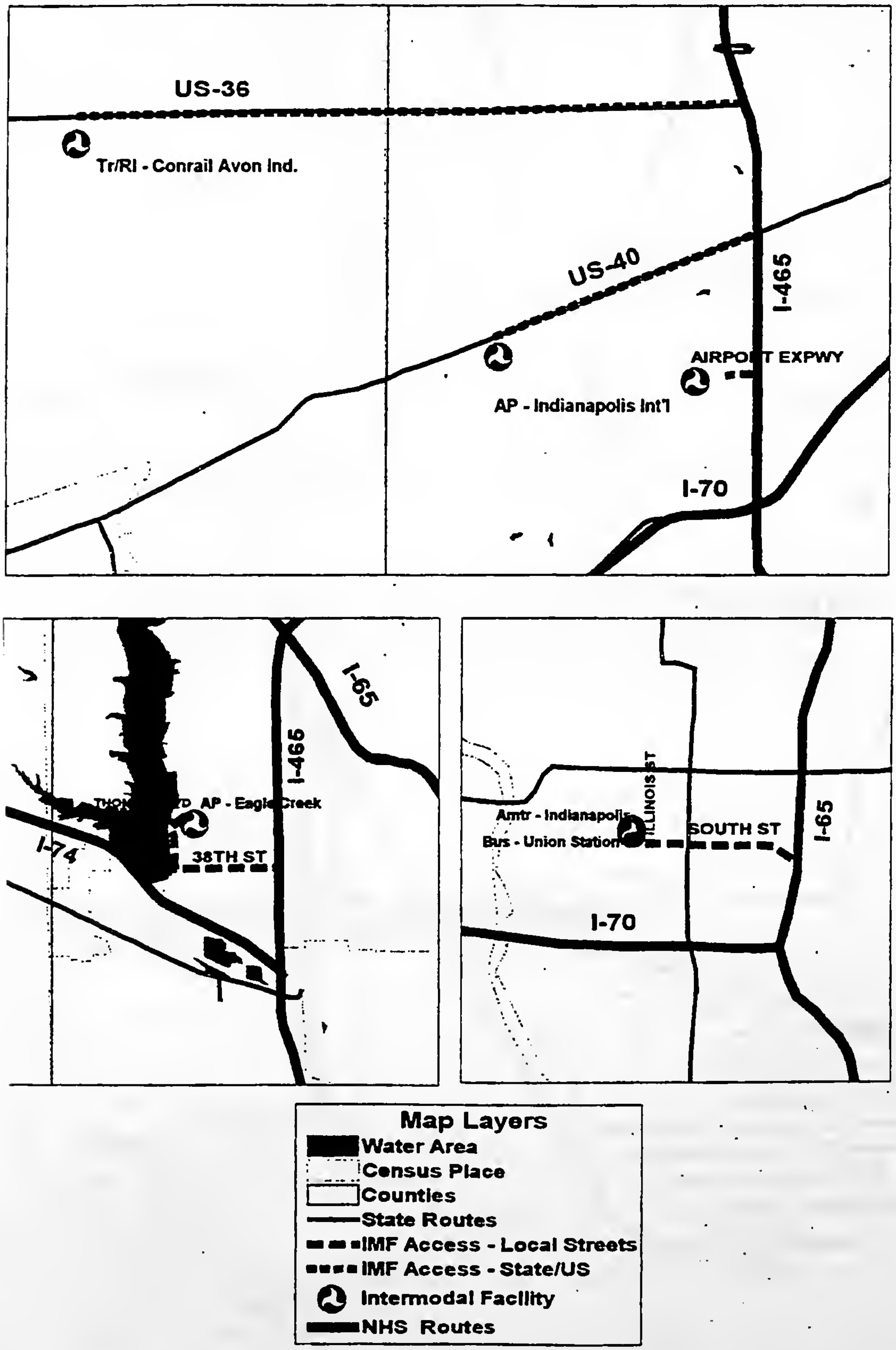
APPENDIX B5.5(h): Lafayette and Remington Intermodal Facilities

APPENDIX B5.5(i): Kokomo and Anderson Intermodal Facilities

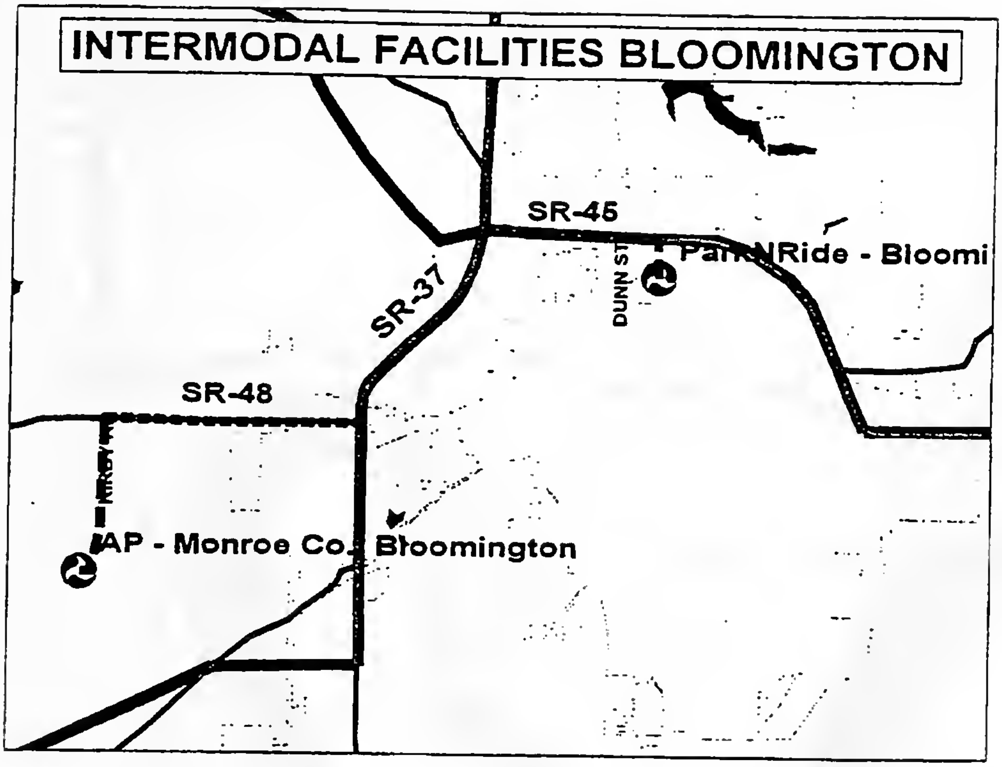


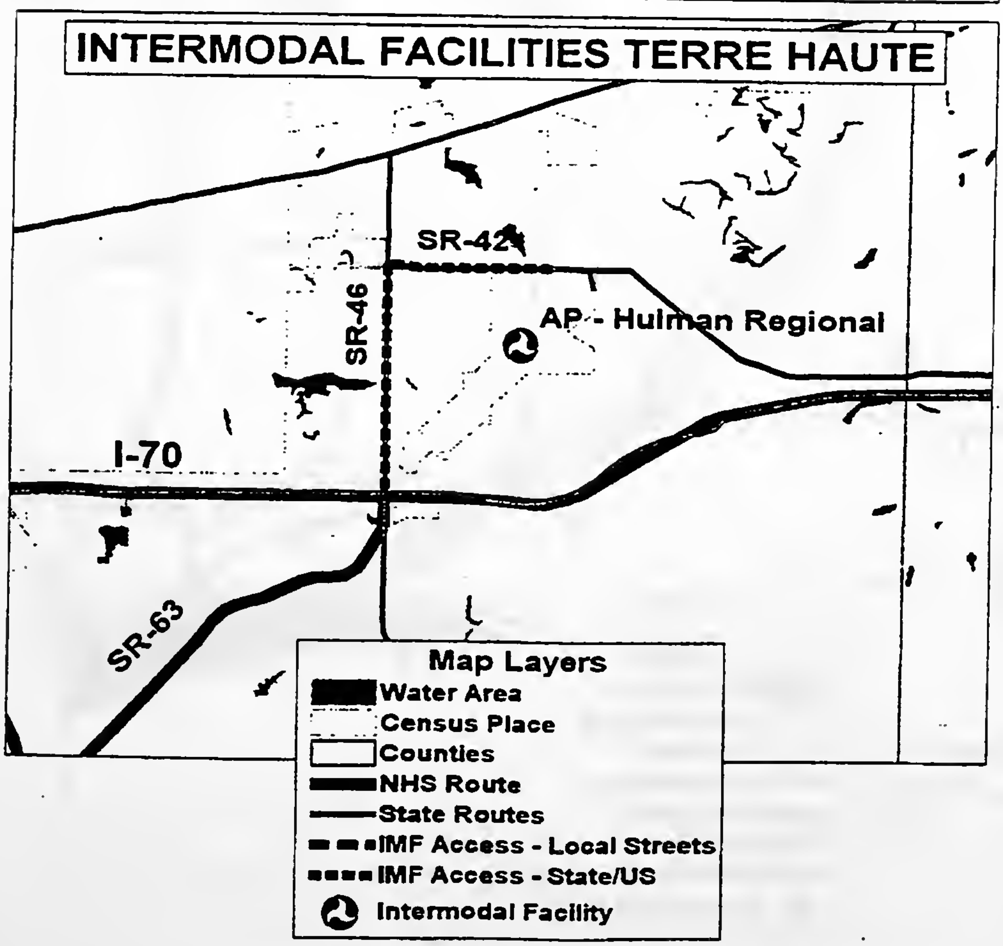


INDIANAPOLIS INTERMODAL FACILITIES



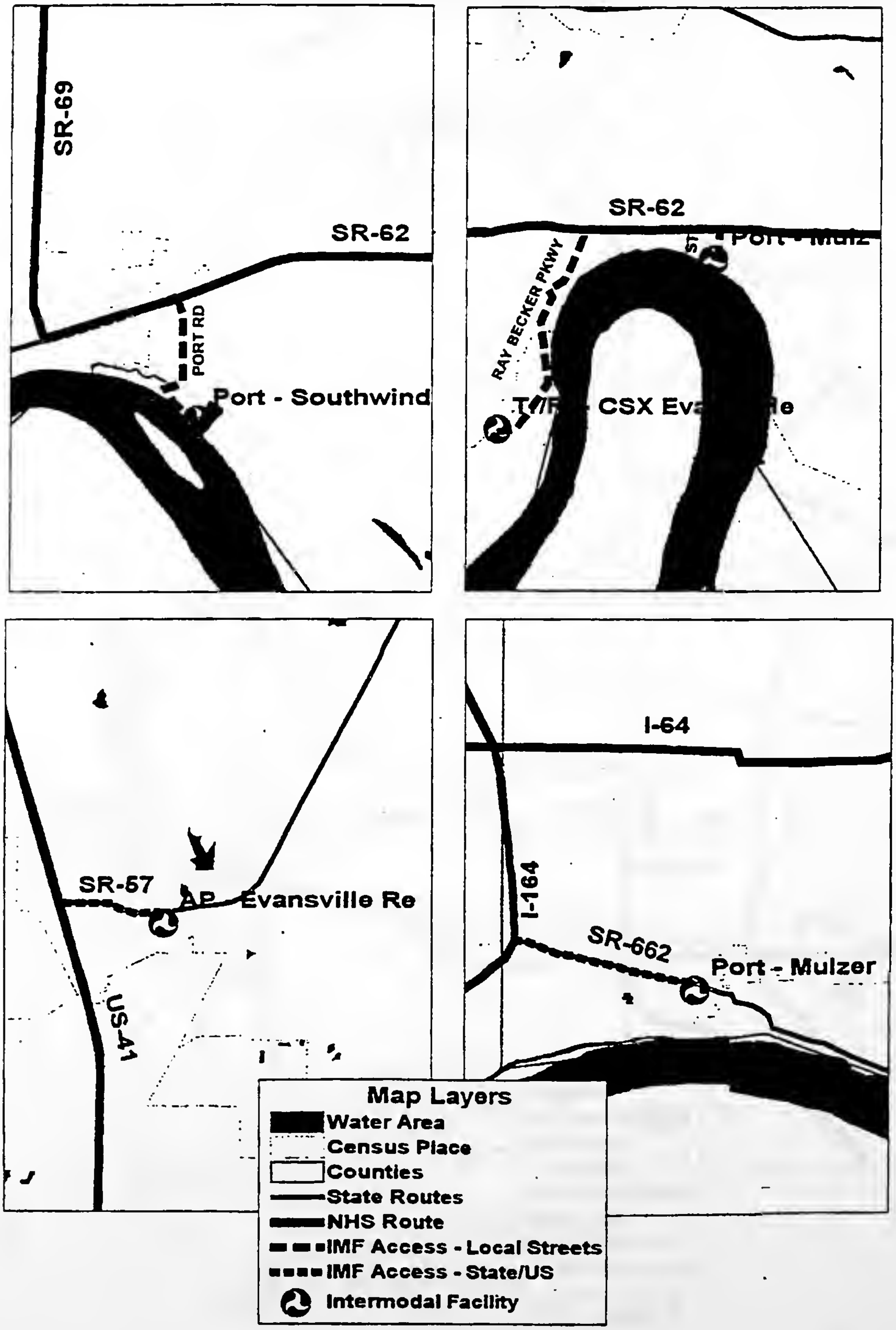
APPENDIX B5.5(j): Indianapolis Intermodal Facilities





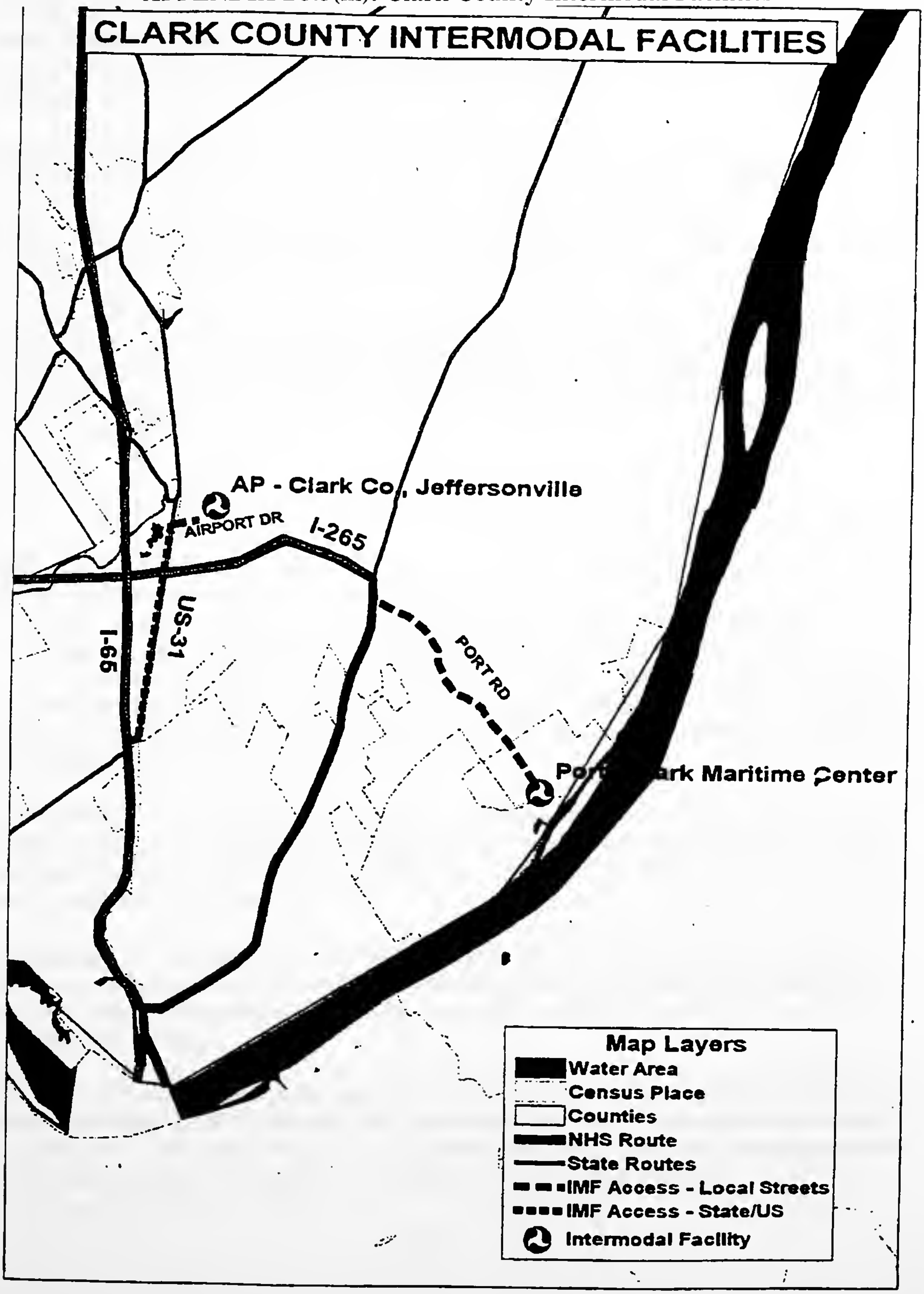
APPENDIX B5.5(k): Bloomington and Terre Haute Intermodal Facilities

EVANSVILLE INTERMODAL FACILITIES



APPENDIX B5.5(l): Evansville Intermodal Facilities

APPENDIX B5.5(m): Clark County Intermodal Facilities



DRAFT TMS/H Data Action Plan **B6**
Public Transportation Facilities and Management System (PTMS)
Jon D. Fricker, Purdue CE, 317-494-2205, FAX 317-496-1105
September 21, 1998

INDOT Contact Person:
Scott Deloney, Public Transit Section, GCN901, 317-232-1591, FAX 317-232-1499

INDOT Work Plan Activity: *Adequacy/accuracy of existing data collection process to satisfy the needs of the Public Transportation Management System*

23 CFR Chapter 1, Subchapter F (Transportation and Infrastructure Management), Part 500 (Management and Monitoring Systems), Subpart F (Public Transportation Facilities and Management System), Section 500.607(b)(2), *Federal Register*, 1 December 1993, p. 63482: "Data related to highway transit vehicles and ridership will be collected as part of the highway monitoring system ..."

REQUISITE TRAFFIC DATA

Most data required for the PTMS do not rely on the current data collection activities of INDOT's Roadway Management Division. This is because ...

a. Much of the PTMS concerns the condition of vehicles and physical facilities.
b. Data concerning transit ridership are routinely collected by the transit provider.
c. In most cases, public transportation service is provided in urban areas where an MPO or other planning or engineer's office collects and maintains highway traffic data. In rural areas, highway-related data are less important, because of the absence of congestion and the higher proportion of "captive" transit riders.

The PTMS highway data requirements quoted above from the *Federal Register* call for "ridership data ... at the maximum load points for the peak period in the peak direction and for the daily time period." These ridership data are to be collected for "dedicated [transit] rights-of-way", which are rare in Indiana.

Furthermore, it is not made clear whether the peaks are defined in terms of *transit ridership* or *roadway traffic flow*. If the former, then the transit provider is the best source of such data. If the latter, then roadway traffic counts in the transitway corridor for a series of consecutive time intervals are required.

INDOT traffic counting equipment can collect traffic volume data for time intervals less than one hour, but standard INDOT procedure uses the one-hour interval. If smaller time intervals (such as 15 minutes) are thought to be necessary to define "street peaks" and local agencies are unable to provide such data, then "special needs counts" can be requested of INDOT.

DRAFT TMS/H Data Action Plan **B7**
Highway Performance Monitoring System (HPMS)
Samuel Labi and Jon D. Fricker
September 21, 1998

INDOT Contact Person:
Marcia Gustafson, Roadway Management Division, GCN808, 317-232-5463, FAX 317-232-5478.

INDOT Work Plan Activity: *Adequacy/ accuracy of existing data collection process to satisfy traffic data needs of the Highway Performance Monitoring System.*

23 CFR Chapter 1, Subchapter F (Transportation and Infrastructure Management), Part 500 (Management and Monitoring Systems), Subpart A (General) Section 500.103, *Federal Register*, 1 December 1993, p. 63475: " [The Highway Performance Monitoring System] includes an inventory of the nation's highways including traffic volumes. "
Also, Subpart H (Traffic Monitoring Systems for Highways), Section 500.807(b), *Federal Register*, 1 December 1993, p.63484: "Traffic Data...shall be to the statistical precision ... specified by the data users ... [and] the statistical precisions established by FHWA for HPMS."

With the acceptance of the Interim Final Rule *(Federal Register*, 19 December 1996), numbering of the above-quoted sections has been changed as follows: Section 500.103 remains unchanged, while Section 500.807(b) is now 500.204(b).

A. TRAFFIC DATA NEEDS:

1. **Type of data required (count types)**:
   * Traffic volumes (AADT and DVMT)
   * Vehicle classification (Percentages of single and multiple units: for both peak hour periods and entire 24-hour periods)
   * Truck loads (this is currently not a reportable item, as it is not indicated as such in *HPMS Field Manual*, even though it is stated as a requirement in FHWA's *Traffic Monitoring Guide)*
2. **Frequency and duration**:
   3- year maximum count cycle length
   48 hour minimum count duration
3. **Number of data collection sites**:
   Traffic volumes - at all HPMS sample sections.
   Vehicle Classification - 300 sites selected from the traffic volume sites
   Truck weights - 90 sites selected from the vehicle classification sites (See comments under "Type of data required").
4. **Distribution of data collection sites**:
   For each count type, data collection sites should be representatively distributed among the various strata (functional classes) and substrata

(volume groups). The nature of the road network is such that this would also yield a balanced spatial distribution.

Chapter 1, p. I-1 of the *HPMS Field Manual* states that the primary purpose of the HPMS is to "...serve highway and transportation data and information needs to ... support all aspects of the functions and responsibilities of the Federal Highway Administration." In this manual, the HPMS is described as a nationwide inventory system that assesses system lengths, use, condition and operating characteristics of highway infrastructure. Operating characteristics include volumes, classification and weights of highway traffic. In p. I-7 of the *HPMS Field Manual*, it is stated that the responsibilities of the state highway agencies include "collection/assembly and timely reporting of high quality HPMS data in prescribed codes and formats." On page I-8 of the manual, it is stated that the role of the MPOs in the HPMS is expected to increase significantly because of the increased responsibility placed on them by recent air-quality and surface transportation legislation, particularly for urbanized areas that have been designated as NAAQS non-attainment areas by the EPA.

The importance of HPMS data in apportionment and allocation of federal funds is emphasized by the HPMS Field Manual (p. I-8): " ... HPMS data items are used to ... derive lane miles and vehicle travel that are entered into [a] formula to annually apportion Interstate Maintenance program funds. Because of this use, these data receive high visibility, and *both the FHWA and the States have special responsibilities to assure that these data are consistent, current, and accurate*." The manual further states that highway safety funds and motor-carrier assistance program safety funds are distributed among the States based on road length and vehicle travel, among other considerations.

Chapter 1, Section 2 of the *Traffic Monitoring Guide (TMG)*, Third Edition, February 1995, p. 2-1-2, states that the structure of the traffic monitoring sample design consists of three major elements, one of which is the HPMS (coverage) element. The Guide further states that the HPMS element consists of the following sub-elements: traffic volume, vehicle classification and truck weight.

On p. 2-3-4 of the TMG, it is stated that, "The HPMS element provides a minimum coverage framework of short counts for AVDT and AADT estimation ... The guidelines of the HPMS (coverage) element recommend the use of 48-hour counts on the full sample of HPMS sections over a three-year cycle." AVDT refers to Annual Vehicle Distance Traveled, while AADT is Annual Average Daily Traffic. On page 3-3-4, under the section titled "Monitoring Cycle Specification", the TMG further states: "This guide recommends a 3-year cycle for traffic volume, vehicle classification and truck weight monitoring." The TMG does not explicitly state whether the recommended 3-year cycle is one that has a base year and is therefore renewed every three years, or whether it is a rolling cycle that renews itself each year. If the former were the correct interpretation, then it would be allowed for the counts to be carried out in any order within the three years, e.g., fewer counts in one year, and more counts in another (such as 50-50-200 for vehicle classification), or same number of counts in each of the three years (such as 100-

100-100 for vehicle classification). However, in the case of the latter interpretation, such flexibility would not be enjoyed, because each of the three years *must* have the same number of counts, so that over *any* three year cycle, the total number would equal the recommended minimum.

The phrase "full sample of HPMS sections over *a* three-year cycle" on p. 2-3-4 of the TMG is suggestive of the former interpretation, otherwise it would have read: ...over *any* three-year cycle." Notwithstanding this indication, the TMG, on page 5-2-2, states that "[the 300-number vehicle classification sample] consists of 100 measurements annually", i.e., 100-100-100. Also, on page 5-2-3, "the [90-number truck weight] sample consists of ... 30 [measurements] each year." It is therefore clear that the HPMS counts should be associated with a base year, and that the number of counts should be evenly spread over the three year period. With such an arrangement, both interpretations would hold.

According to the TMG, page 2-2-1, the HPMS universe consists of all public highways or roads within the state. The reporting strata for the HPMS standard sample include type of area (rural, small urban, and individual or collective urbanized areas) and functional class. In rural areas, the classes are Interstate, Other Principal Arterial, Minor Arterial, and Major Collector; the Local and Rural Minor Collector systems are not sampled. A third level of stratification based on volume was added as a statistical device to reduce the sample size and to ensure the inclusion of higher volume sections in the standard sample. Appendix F of the *HPMS Field Manual* provides a complete definition of the stratification levels. A copy of this section of the manual is provided in Appendix B7.8 of this data action plan.

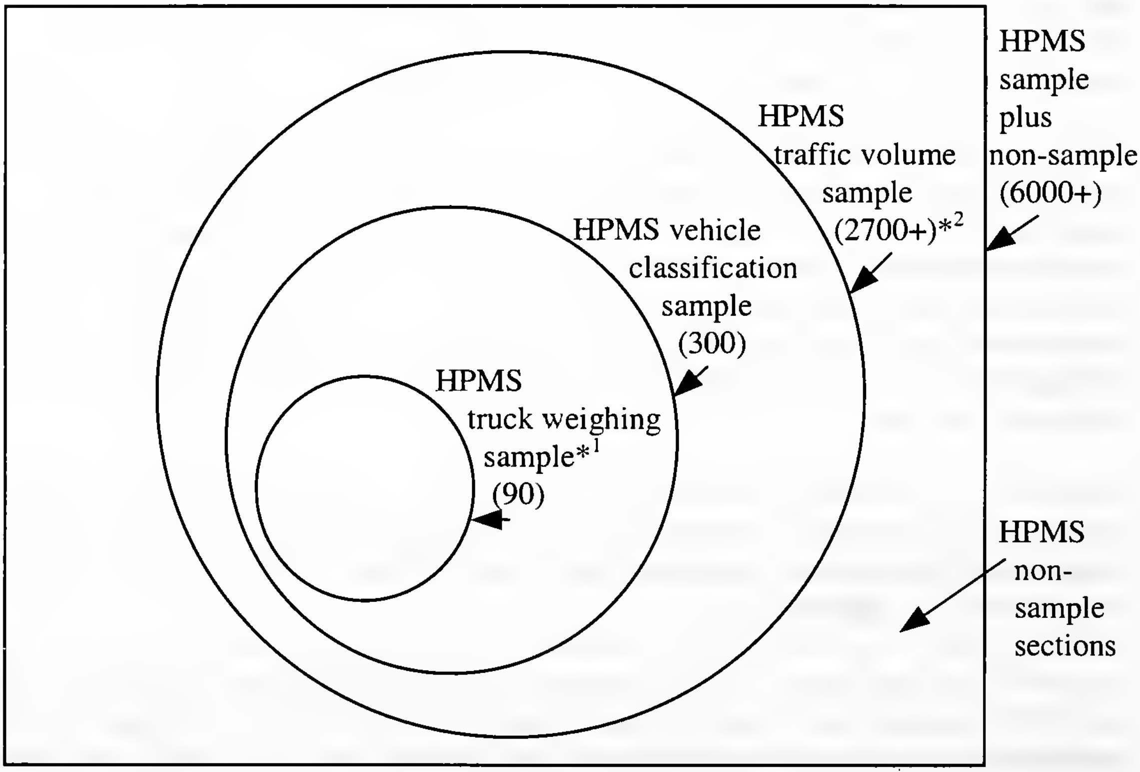
INDOT uses a terminology for the HPMS universe that is somewhat different from that in the TMG. At INDOT, the "HPMS universe" is described as the collection of only the non-sample HPMS sections, rather than the entire collection of all public highways (both sample and non-sample sections).

The HPMS standard sample design is a stratified simple random sample (TMG p. 2-2-1). The HPMS standard sample-size estimation process is tied to AADT, although about 80 data items are collected. According to the TMG, the decision to use AADT was partly based on the fact that AADT is the most variable data item in the HPMS. Therefore, the reliability of most other characteristics would be expected to exceed that of AADT.

On page 1-3 of the *HPMS Field Manual*, under the section titled "Overview of HPMS Reporting Requirements", it is stated that: " the HPMS requires the reporting of area-wide data, universe data, standard sample data, and HPMS linear referencing system data for geographical information systems [GIS]." The GIS is a system of hardware, software and data for collecting, storing, analyzing, and disseminating information about areas of the Earth. For HPMS purposes, the HPMS Field Manual defines a GIS as " a highway network (spatial data which graphically represents the geometry of the highways) and its geographically referenced component attributes (HPMS section data ... and other data ...) that are integrated through a GIS technology to perform analysis".

The *HPMS Field Manual* does not indicate any reporting requirements for 48-hour truck weights. However, the *Traffic Monitoring Guide* suggests that collection of short-term truck weight data may be carried out. This study has been carried out to include truck weights for possible future reference and use, should that count type be confirmed as a reporting requirement. Meanwhile, the results of the truck weight section of this data action plan could be useful for the operations of INDOT's Traffic Statistics Division.

The HPMS traffic monitoring structure recommended by the *Traffic Monitoring Guide*, and that may be applied to INDOT's HPMS traffic monitoring program is illustrated as follows:



Number of sample sections in each category shown in parenthesis.
*1: Reporting of truck weights is currently not a reporting requirement for HPMS.
*2: The traffic volume sample over a three-year cycle, is equivalent to the entire HPMS sample.

B. INFORMATION ON THE EXISTING SITUATION

1. **Data collection locations and equipment:**

Currently, the traffic volume and vehicle classification aspects of the coverage count program are being carried out at HPMS sections to obtain data for the HPMS reports.
These counts are carried out by INDOT at all HPMS sections, with the exception of those non-state HPMS sections in the urbanized areas which are monitored by the Metropolitan

Planning Organizations (MPOs). A description of MPO activities including the number and distribution of HPMS counts they carry out is provided as Appendix 5 of the main report.

For coverage counts at HPMS sections, pneumatic road tube equipment, installed by mobile field crews, are used. Each of such installations consists of pneumatic tubes installed at right angles to traffic lanes across the roadway with one end plugged. Tube clamps are held down with spikes or nails, depending on the pavement type. The tube is made taut enough to guarantee minimum motion when crossed by a vehicle traveling at the posted speed, but not so tight as to cause undue strain on the clamps. The weather-proof recording unit is placed on one side of the roadway. For vehicle classification activities, two tubes are used.

There is no on-going coverage count program for truck weights at HPMS sections, because there is no indication in the *HPMS Field Manual* that truck weight data need to be reported. Otherwise, truck weight data for HPMS reports could be obtained from WIM equipment at existing ATR sites, and possibly supplemented by short-term counts using portable equipment. INDOT has recently reactivated an experimental portable truck-weighing exercise.

The table on the last page of Appendix 1 of the main report for this study shows details of the equipment currently used for the coverage (HPMS and CFM) count program.

2. **Data collection personnel**

The table provided in Appendix 2 of the main report for this study shows the various personnel currently responsible for collection of traffic data for the coverage counts. Some of these personnel are also responsible for collection of traffic data for the other elements of INDOT's traffic monitoring program, e.g., the Continuous and Special Needs counts.

C. EVALUATION OF THE EXISTING SITUATION

The *Traffic Monitoring Guide* establishes the need for states to monitor system-level traffic based on short-term traffic "counts" for volumes, classification, and weights. "System-level" refers to the estimate of traffic data for the road system by functional class rather than site-specific estimates.

The HPMS universe is defined as the set of all public highways and roads within the state (TMG p. 2-2-1). According to the TMG, on page 2-6-3, the sample design incorporated into the HPMS element should consist of four major samples:

- HPMS sample (which is a collection of highway segments selected from the state's HPMS universe)

- Traffic volume sample (which, in a given year, is a subset of the HPMS sample, but is equal to the HPMS sample over a 3-year cycle).
- Vehicle classification sample (which is a subset of the traffic volume sample)
- Truck weight sample (which is a subset of the vehicle classification sample)

There are about 6000 HPMS universe sections in the State of Indiana. From this universe, INDOT has selected about 2700 sections that are collectively termed 'the HPMS sample'. In most documents, the term 'HPMS section' refers to a road segment that belongs to the HPMS sample, and not the HPMS universe. This terminology will have the same meaning in this document. Hence the number of HPMS sections will be considered as 2700+, i.e., sample sections, and not 6000+.

The TMG leaves the definition of a "road segment" to the discretion of the states.

In the present situation at INDOT, the degree to which "coverage" short-term data collection activity is pursued is generally determined by a need whose scope extends much beyond that of the HPMS. This count program is carried out for preparation of county flow maps and to determine VMT estimates for each county. This program was in existence before the advent of the HPMS program and has earned the "coverage" description by virtue of its extensive scope. In this document, "coverage counts" refers to counts carried out for HPMS and the CFM system. Sites for HPMS counts are subset of the overall coverage count sites.

The HPMS program, when introduced in 1978, was structured by INDOT in such a way that data were collected for HPMS sections were made a subset of the CFM coverage count sites. Thus the data collection effort for these two count systems was reduced in terms of time and resource allocation.

With the exception of state highways in urbanized areas, traffic data collection for roads in urban areas is generally not the responsibility of INDOT. Whereas traffic data (traffic volume and vehicle classification) are collected by INDOT for all HPMS sections in non-urbanized areas, this is not being done by INDOT for the non-state highway HPMS sections within the urbanized areas. Traffic data collection on non-state HPMS roads at urbanized areas is the responsibility of Metropolitan Planning Organizations under whose jurisdictions such areas fall.

In this study, TMG-recommended methods were followed to assess the adequacy of the HPMS coverage element of INDOT's traffic monitoring program, and to determine the number and distribution of any additional data collection sites. According to the *Traffic Monitoring Guide*, page 4-2-5, "the reason for considering existing ATR sites for inclusion in the recommended distribution of HPMS sites stems from FWHA's recognition that states have invested considerable funds and effort and have obtained historic knowledge from those existing locations. Hence it is desired that the loss of such

investments be minimized by maximum integration of such existing [ATR] sites into the HPMS sample."

a) The HPMS Standard Sample

This sample, according to the *Traffic Monitoring Guide* (TMG), has already been defined and implemented by all states. INDOT has identified all segments on its public highway system that collectively constitute the HPMS universe. From this universe, INDOT has selected the sections that form the HPMS standard sample. There are currently about 6000 and 2700 HPMS universe and sample sections respectively in the State of Indiana. Non-sample universe sections are usually termed "universe sections".

a.1: Check on the adequacy of current sample size:

The *HPMS Field Manual* indicates that the HPMS sample size depends upon the coefficients of variation of the AADTs on HPMS sections and may therefore not necessarily remain constant over a period of time. In this regard, the manual requires that the sample size be based on the latest information. An implication of this requirement is that annual checks are needed to check the adequacy of the current sample size, and even to check the adequacy of the sample size at any future year using projected values of AADT.

The procedure explained below was used to check the adequacy of the current HPMS sample size for the State of Indiana. This procedure is based on the method provided in Appendix G of the *HPMS Field Manual*, subtitled "Sample Size Estimation Procedures".

The sample size estimate for each stratum is derived from the following formula:

$$n = (Z^2C^2/d^2) / [1+(1/N)(Z^2C^2/d^2 - 1)]$$

where

n = required sample size
Z = value of the standard normal statistic for alpha confidence level (2-sided)
C = AADT Coefficient of Variation from the state's AADT data
d = desired precision rate
N = universe or population stratum size

Using this formula, the sample size, i.e., number of samples needed for each stratum were found. Details of these calculations are provided as Appendix B7a (iv).

Sample calculation

For Volume Group 03 of the Small Urban Interstate stratum with a desired precision of +5% with a 90% confidence level that corresponds to a Z statistic of 1.645, an AADT variation coefficient of 0.112 (see Appendix B7a(iv)), and 10 available universe sections (see Appendix B7a(iv)), the required sample size is

$$n = Z^2C^2/d^2 \ / \ [1+(1/N)(Z^2C^2/d^2 - 1)]$$

$$= 1.645^2 * 0.112^2/0.05^2 \ / \ [1+(1/10)*(1.645^2 * 0.112^2/0.05^2 - 1)]$$
$$= 6.0334 \ (= 7, \text{approximately})$$

It can be seen that the critical factor in the determination of sample size is the designation of the parameter C, i.e., the AADT variation coefficient. According to the *HPMS Field Manual*, the original HPMS design was based on empirical estimates using data from a small number of states, and that the procedures presented in that section of the manual require estimation of AADT values based on the latest data values available, so as to obtain up-to-date estimates of sample size tailored to each specific state.

The *HPMS Field Manual* further states that the AADT coefficients of variation may be generated from a state's universe data using standard statistical computer packages if accurate AADT data are available on most of the arterial/collector records. Otherwise, the existing sample data should be used for generating the coefficients.

a.1.1: Discussion of the results of the adequacy analysis of the current size of the HPMS standard sample:
An adequacy analysis for the HPMS standard sample for the current year was carried out by comparing the required number of HPMS sample sections to the existing number of such sections, for each volume group. Table B7a(ii) shows a summary of this analysis, while computational details are provided in Tables B7a(iii) and B7a(iv). An "undersized" volume group refers to a volume group whose existing sample size is smaller than the required size, while an "oversized" volume group is one with a sample size larger than the required size. It is therefore possible for a *functional class* to have both undersized volume groups and oversized volume groups. The discussion below is done for each functional class.

Rural Interstates: This functional class requires only 3 additional HPMS sample sections. 47 sample sections in various volume groups in this class could be deleted in this functional class without affecting the statistical validity of the HPMS sample for volume groups in this functional class.

Rural Other Principal Arterials: No additional HPMS sections are required for any volume group within this functional class. However, a total of 139 sample sections are found in oversized volume groups, and may be deleted from the HPMS standard sample.

Rural Minor Arterials: An equal number of additional and excess sample sections, i.e., 27, were observed for this functional class.

Rural Major Collectors: This is one of the few functional classes for which the additional number of sites needed (15) exceeds the number of excess sites (7).

Rural Minor Collector and Locals: No additional nor excess sections were obtained for these functional classes. However, this does not mean that the current sample sizes for all volume groups in these two functional classes are perfectly adequate. From Table B7a(iv), it can be seen that all component sample sections within a volume group were assigned the same AADT. Thus a zero value for the AADT coefficient (and corresponding zero number of sites required) was obtained. It is clear that this uniform assignment of AADT values does not reflect the true state of affairs. This practice must be avoided, at least for the Rural Collector HPMS sample sections. Actual counts must be carried out for these sections. For starters, a sample size of about 25% of the total universe size may be used, and this size may be updated in the following year based on the AADTs obtained during the first year of implementation of actual counts.

Small Urban Interstates: For this functional class, only 2 additional sections are required, while there are 7 sections that could be deleted from the standard sample. This case is one of the closest to complete adequacy of the sample size.

Small Urban Other Freeways and Expressways: The deficiency of the HPMS sample for this functional class is reflected in the observation that there are no excess sample sections in any volume group, while a total of 9 additional samples are required. The 9 samples should be selected from the 29 non-sample universe sections available in this functional class on a volume group basis.

Small Urban Other Principal Arterials: A total of 194 excess sample sections was observed, and these could be deleted. Also, 26 additional sites are required for undersized volume groups, and may be selected from the vast pool of 460 non-sample universe sections.

Small Urban Minor Arterials: Only 1 additional section is needed, while 21 sections in oversized volume groups are in excess and may be deleted from the standard sample.

Small Urban Collectors: For this functional class, 9 and 33 sites were observed as additional and excess number of sections, respectively.

Urban Interstates: A near-perfect state of sample-size adequacy was observed for this functional class. Only 2 excess sections are encountered, while no additional sections are needed.

Urban Other Freeways and Expressways: A total of 5 additional sample sections are required for various undersized volume groups in this functional class, and there are 2 excess sites that could be deleted.

Urban Other Principal Arterials, Urban Minor Arterials and Urban Collectors: For Urban Other Principal Arterials, a very large number of excess sections was observed,

and only 1 additional section is needed. A similar observation was made for the Urban Minor Arterials and the Urban Collectors.

Large Urban Interstates: While no additional sample sections are needed, a total of 51 sections is in excess and may be deleted.

Large Urban Other Freeways and Expressways, Large Urban Other Principal Arterials, Large Urban Minor Arterials and Large Urban Collectors: All these functional classes have very few additional sample sections needed but have relatively large numbers of excess sections that may be slated for deletion.

Large Urban Locals: There are no excess sample sections for this functional class, but 8 additional sample sections are required. Because local roads are excluded from the HPMS sample, the observations made for this functional class may be ignored.

Conclusion: Since the last design of the HPMS standard sample, there have been significant changes in traffic volume patterns within each volume group to warrant changes in the size and distribution of the standard sample. On the basis of the results of analyzing 1996 data, it is suggested to implement appropriate changes as discussed in the next paragraph.

In all, it was found that a total of 127 additional sections are required for various undersized volume groups, while a total of 1545 sections are in excess and could be deleted without adversely affecting the statistical validity of the HPMS sample. This means that the size of the current HPMS standard sample is, in general, far too large. The sample could be therefore be pruned down in order to achieve overall economy in the data collection activities for the HPMS. Deleted sample sections revert to the status of non-sample HPMS universe sections.

Additional sections required for undersized volume groups may be selected from the non-sample HPMS universe, with preference given to sections with highest volumes.

a.2: Framework for checking adequacy of sample size at future periods:
The volume of traffic at any HPMS sample section changes from year to year. It is therefore possible that an HPMS section would change its volume group from one year to the next. Usually, such migration is from a lower volume group to a higher one, due to increasing traffic at most locations.
Another issue is that the magnitude and direction of the rate of growth is not uniform. Some sections may experience higher growth rates than others. Also, while most sections are expected to see increased traffic over the years, some sections may actually have a decline in traffic volumes.

The effect of these two issues is that within any functional class, the number and composition of volume groups may be significantly different from one year to the other. Also, the AADTs associated with the constituent sample sections in any volume group would have different values and a different pattern of variation. This pattern of variation, expressed by the AADT coefficient of variation for that volume group, is the main factor that determines sample size.
It is therefore necessary for INDOT to continue carrying out adequacy analysis every year to assess the migration of HPMS sections across volume groups and to determine whether changes in sample size in each volume group are needed for monitoring during the following year. This could be carried out at the end of the year, so that any needed changes could be implemented early in the following year. That way, any possible lag between recommendations and implementation can be avoided. In addition, INDOT may carry out the adequacy analysis for future years using projected values of AADTs based on current trends. While growth factors may not be flawless indicators of future traffic levels, such an approach would at least provide reasonable estimates of future AADTs and the corresponding number of sample sections needed, so that INDOT can plan ahead for resources that may be needed to monitor traffic for the HPMS sample in future years.

Two different approaches may be used to generate alternative growth factors for this exercise:

a) The Functional Class Growth Factors approach, where all AADT values for HPMS sections in a given functional class were increased by the same factor. These figures, available at INDOT, are based on previous growth patterns for each functional class.

b) The County Growth Factors approach, where all AADT values for HPMS sections for road segments of the same functional class in a particular county were increased by the same figure. These figures can be obtained from study carried out by Clark and Fricker (1994). This approach involves the use of county-specific statistics such as population, number of licensed vehicles, etc.

Both approaches yield factors that adequately provides for traffic growth at road sections, and make it possible to monitor the migration of sections from one volume group to the other. However, the former approach would involve a blanket application of the same factor for all sections in an entire volume group. Therefore, by using this approach, the projected AADT coefficient of variation for a volume group would remain the same as that for the previous year. The new required number of sites for that volume group may therefore change only very slightly from the previous year, because the only changed parameter may be the total number of HPMS universe sections in that volume group.

The latter approach does not have this shortcoming. Component HPMS sample sections in a volume group belong to different counties, and with the application of county growth factors, different rates of growth will be encountered. Thus, the picture of variation would be different from that of the previous year. An AADT coefficient of variation

significantly different from that of the previous year would yield a different number of sample sections required for that volume group.

Application of selected growth factors to base year AADTs on HPMS sample sections is a possible subject of future study. The results of such an analysis will indicate the new composition of each volume group and the required number of sections, at specified future years.

b) The HPMS Traffic Volume Sample

Introduction:

According to the *Traffic Monitoring Guide (TMG)*, p.3-1-1, the measurement of traffic volumes is one of the most basic functions of highway planning and management. HPMS traffic data aids in the estimation of Vehicle-Miles-Traveled (VMT) and are also used for application of seasonal factors to arrive at AADT estimates.

The objectives of this section of the study is to determine the adequacy of the existing number of HPMS volume counting stations and the distribution of any additional such stations.

(i) *Sample size*: The recommended size of the traffic volume sample (i.e., number of HPMS sections on which coverage counts for volume should be performed every year) is one-third the total HPMS sample size.

According to the *Traffic Monitoring Guide*, as a first step, the locations of existing continuous count (ATR) sites should be examined to determine which can be incorporated into the HPMS volume count program, so that the number of sites needed to be set up specifically for HPMS can then be found by subtracting the number of usable ATR sites from the total number of HPMS sites needed.
Finally, the required number of HPMS sites should be compared to the existing number and distribution of HPMS sites to assess the adequacy of the latter.

Currently there are about 2700 HPMS standard sample sections in the State of Indiana. This means that coverage counts for traffic volume should be carried out at an average of 900 HPMS sample sections per year.
Using information gathered from relevant documents made available by the Traffic Statistics Section of INDOT and MPO data, it was found that the total annual size of the HPMS traffic volume sample has grown to 1075 in 1996. This shows that INDOT has undertaken increasingly successful efforts, over the years, to meet the HPMS traffic volume reporting requirement have now shown success. Details of these counts are provided as Appendix B7 b(ii), while a summary of these details is shown on Table B7 b(i.)

(ii) *Frequency*: *The Traffic Monitoring Guide*, in Section 3-3-1, requires that the traffic volume monitoring sample corresponds to the HPMS sample at the completion of a three-year cycle. From the discussion in the previous section, it is clear that the current

monitoring frequency for the traffic volume sub-element of the HPMS coverage count is generally not in accordance with established guidelines, even though there are measures currently in place by INDOT to improve the situation. Most MPOs carry out counts over a three year cycle. A few MPOs do not currently meet this requirement, but are striving to do so.

(iii) *Duration of monitoring*: The minimum 48-hour duration currently being used for the traffic volume count on HPMS sample sections in all areas of the state, including MPO areas, is in line with the recommendations in Section 3-3-1 of the *Traffic Monitoring Guide*.

(iv) *Distribution*: Section 3-3-9 of the *Traffic Monitoring Guide* states that the selection and distribution of the HPMS sections in the traffic volume sample (also referred to by the TMG as the "core sample") must be conducted randomly to maintain statistical validity.
The Guide further states that such statistical validity requires random spatial (geographical) and random temporal (calendar year) distributions.

In Section 3-3-9 of the TMG, it is stated that "*the HPMS standard sample, by virtue of its extensive stratification and random selection, already provides a balanced spatial distribution.*" According to INDOT, the 2700+ HPMS sample sections in the State of Indiana were obtained through such "extensive stratification and random selection", and can therefore be considered as a balanced spatial distribution.

Table B7b(i) Summary of HPMS traffic volume counts carried out within 1992-1996
(See details in Appendix B7-b(ii))

Year	1992	1993	1994	1995	1996
Overall Total	385	355	273	861	1075

Traffic volume data collection activities are carried out by INDOT on all HPMS sample sections. However, it is clear that this is done over a cycle much longer than the specified minimum of 3 years, due to the fact that the current resources are not adequate to achieve the desired situation.

c) The HPMS Vehicle Classification Sample

Introduction:
Vehicle classification is the observation of highway vehicles and the subsequent sorting of the resulting data into a fixed set of categories depending on the size, axle configuration, and type of vehicle. Vehicle classification data are of immense use to agencies involved in almost every aspect of transportation planning, engineering, and finance. Examples of activities that make use of vehicle classification data include pavement analysis and design, and pavement management, predicting commodity flows

and freight movements, providing design input relative to current and predicted capacity of highways and analysis of alternative highway regulatory and investment policies.

An assessment of INDOTs HPMS vehicle classification counts program has been carried out by determining the adequacy of the existing number of HPMS vehicle-classification sites and distribution of any additional number of such sites.

(i) Sample size and frequency of counts

c.(i)-1: <u>Required sample size</u>
Part 1: Determination of the number of vehicle-classification HPMS sections needed for each functional class:
The recommended size of the HPMS vehicle classification sample (i.e., number of HPMS sections on which coverage counts for classification should be performed) is 300 over a three-year cycle (*Traffic Monitoring Guide* p. 2-4-5). This set should be a subset of the HPMS traffic volume sample. The distribution of these HPMS vehicle classification sites is then found by stratification using the table attached as Appendix B7c(ii). This form, a separate one of which is used for each substratum (e.g., rural interstate), follows a procedure in which the sample size for vehicle classification for each substratum is found by simple proportion. The vehicle-distance traveled is used to find the VMT weighting factor, and then to determine the sample size for each substratum.

For example, the Indiana rural interstate system carries 12.48% of the total traffic (excluding Rural Minor Collectors and Locals) in the state in terms of vehicle-miles traveled (INDOT HPMS Report, 1995). Therefore, 12.48% of 300 sample sections corresponds to 37 HPMS samples per 3 years, or about 12 HPMS classification samples a year, for Rural Interstate.

Part 2: Further stratification by volume groups, and reduction of the HPMS data collection effort by incorporation of existing ATR sites into the HPMS program:
According to the TMG, the locations of existing continuous counts sites (ATRs) should be examined to determine which can be incorporated into the HPMS vehicle classification program, so that the number of pure HPMS sites, i.e., sites needed to be set up specifically for HPMS for vehicle classification, can then be found by subtracting the number of usable ATR sites from the total number of HPMS sites needed.

The overall required number of HPMS counts is then compared with the existing number of HPMS and usable ATR count sites, and recommendations are made, if necessary, to increase the number of existing count sites designated for HPMS vehicle classification.

The forms designed for this analysis are based on the approach described on pages 4-2-1 and 4-2-2 in the *Traffic Monitoring Guide*.

Table c(i)-1: Distribution of **required number** of vehicle classification counts at HPMS sample sections over a three-year cycle

Sub-stratum	Road Extent (mi)	DVDT 1000's (a)	DVDT (% contribution)	Total # of sites needed over 3-year cycle
		a	c = a/b	d=c*300
Rural Interstates	852.53	17935	12.48	37
Urban Interstates	319.30	21833	15.20	46
Urban Other F'ways & Expressways	132.22	2971	2.07	6
Rural Other Principal Arterials	1699.6	15208	10.59	32
Urban Other Principal Arterials	1546.8	23740	16.53	50
Rural Minor Arterial	2246.6	11904	8.29	25
Urban Minor Arterial	2417.4	16382	11.40	34
Rural Major Collector	10685	27799	19.35	58
Urban Collector	2200.4	5881	4.09	12
Total		143653 = b		300

c (i)-2: **Existing number** of counts at sample sections
Details of existing HPMS vehicle classification counts are provided as Appendix B7 c(ii), while a summary of these details is shown on Table B7 c(i.)

Table B7c(i) Summary of HPMS vehicle classification counts carried out at HPMS sample sections within 1994-1996 *(See details in Appendix B7-c(ii))*

Year / *Functional Class*	1994	1995	1996	Total
Rural Interstates	8	26	17	51
Rural Other Principal Arterial	21	29	37	87
Rural Minor Arterial	11	12	11	34
Rural Major Collectors	2	27	5	34
Urban Interstates	8	10	12	30
Urban Freeways & Expressways	0	3	10	13
Urban Other Principal Arterials	19	11	11	41
Urban Minor Arterials	1	12	6	19
Urban Collectors	0	0	1	1
Total for each year	70	130	112	312

Total for the three year count cycle period = 312 HPMS vehicle classification counts

A breakdown showing the details of the calculation is provided as Appendix B7.cii.

Table B7c(ii) Comparison of the required and existing number of vehicle classification (v.c.) counts at HPMS sample sections, 1994-1996*1

Functional Class	Required number of v.c. counts at HPMS sample sections	Existing number of v.c. counts at HPMS sample sections	Comments
	a	*b*	$c = a - b$
Rural Interstates	36	51	O.K. (25 excess)
Rural Other Principal Arterial	31	87	O.K. (56 excess)
Rural Minor Arterial	24	34	O.K. (10 excess)
Rural Major Collectors	56	34	26 needed *1
Urban Interstates	44	30	14 needed *1
Urban Freeways & Expressways	6	13	7 excess
Urban Other Principal Arterials	48	41	7 needed *1
Urban Minor Arterials	33	19	14 needed *1
Urban Collectors	12	1	11 needed *1
Total	300	310	

*1: Vehicle classification data collection activities on HPMS sample sections are carried out by INDOT on a much wider scale than is indicated above. However, this is done over a cycle much longer than the specified minimum of 3 years, due to the fact that the current resources are not adequate to achieve the desired situation. Therefore sections that are indicated on the above table as being "needed" are actually covered by INDOT's classification coverage count program, albeit over a cycle of 4-6 years. It has not been possible to attain a consistent 3-year cycle due to lack of resources.

The *Traffic Monitoring Guide* requires that 300 HPMS vehicle classification counts should be carried out at the completion of a three-year cycle. Table B7.c, which compares the required and existing situations, shows that the number of vehicle classification counts carried out by INDOT at HPMS sample sections is generally satisfactory.

Counts from the MPOs were not included in this analysis for two reasons: (i) most MPOs carry out only volume counts, even though most of the volume-counting equipment they currently have are also capable of classifying vehicles. This is probably due to the limited staff strength of most MPOs. (ii) The very few number of MPOs that stated that they carry out classification counts for HPMS sample sections did not submit any documentation that indicated the functional classes of these counts.

d) The HPMS Truck-Weighing Sample

Introduction

Decisions concerning such matters as pavement management, pavement design and analysis, equitable tax structures, revenue projections, safety, enforcement, and pavement research require knowledge not only of volumes of traffic using highway facilities and proportion of vehicles of each type, but also the weights of such vehicles. For adequate assessment of pavement life, pavement quality, and the investment levels needed to improve or maintain the systems, it is important that the range and frequencies of the loads imposed upon the facilities are known.

Truck weight and vehicle classification data are used at the state and national levels in the allocation of highway costs and revenue, the formulation of transportation policy, pavement design criteria and selection, truck size and weight regulation, the establishment of geometric design criteria related to the size and weight of vehicles, and various special administrative, planning , design duties and research studies. At the state level, truck weight data are used in calculating pavement loadings in single axle equivalents or other comparable procedures, and in bridge loading analyses. Planning, program budgeting, and evaluations, and other administrative studies require statistically reliable axle, vehicle, and total loadings that can be related to operational characteristics, taxation rates, cost responsibility, and enforcement effectiveness.

This part of the study evaluates the possible continuance of the recently re-activated short-term truck weighing program (and its possible evolution into an HPMS truck weighing program in the event that truck weight data becomes a reporting requirement). The study also determines the number of HPMS truck-weighing sites needed as well as the distribution of such sites in such a manner that would ensure generation of statistically reliable and representative weight data. It is envisaged that such data would adequately provide an indication of spatial and temporal trends in the loading of the highway facilities to support the uses described above. A framework for life-cycle cost analysis has been presented to assist INDOT in deciding the most appropriate equipment type (portable, permanent, or a combination of both) and resources needed for this program.

<u>d.1 The existing situation</u>

d.1.1 Count sites: Currently, there are no short-term counts being carried out for the truck weight aspect of the HPMS program. Also no sites have yet been demarcated for possible implementation of this program in the future. This is because there is no indication in the *HPMS Field Manual* that truck weight data needs to be reported. If it

were so, truck weight data for HPMS reports could be obtained from WIM equipment at existing ATR sites, and possibly supplemented by short-term counts using portable equipment. However, INDOT has recently reactivated an experimental portable truck-weighing exercise for other uses.

d.1.2 Equipment and personnel: As of August 1997, INDOT had 6 capacitance mat sensors and one processing unit that are currently being used on an experimental basis to monitor short-term truck weight data. This is the only equipment presently available for short-term truck weight measurements. The personnel that are currently assigned to field testing and performance evaluation of these experimental portable weigh-in-motion equipment are full time INDOT field technicians already responsible for other traffic monitoring duties.

d.2 The required situation, and recommendations

Even though the *HPMS Field Manual* does not require reporting of short-term truck-weight data, the TMG suggests that this activity may be carried out. This study has been extended to address the HPMS truck-weighing program for three reasons:

- To serve as a contingency for possible future reporting requirements of HPMS truck weight data
- To help support the present vehicle classification aspect of the HPMS, because portable WIM equipment excel in the collection of reliable classification data
- To provide data to support the possible future weight data needs of the Pavement Management System, other agencies involved in pavement research, and project-specific demands

d.2.1 Sample size, count frequency and duration.

Part 1: Determination of number of truck-weighing HPMS sections needed for each functional class:

The recommended size of the HPMS truck-weighing sample (i.e., number of HPMS sections on which coverage counts for classification should be performed) is a minimum of 90 over a three-year cycle (ref. *Traffic Monitoring Guide* p. 2-5-3). This set of 90 sites should be a subset of the HPMS vehicle classification sample. The required minimum duration of monitoring is 48 hours.

The distribution of these 90 HPMS truck-weighing sites among the various functional classes are then found by stratification, using the form B7-D1 attached in the Appendix. This form, a separate one of which would be used for each substratum (e.g., rural interstate) follows a procedure in which the sample size for truck-weighing for each stratum and substratum is found by simple proportion using vehicle-distance traveled, then finding by simple VMT proportion the sample size for each volume group within the substratum of each stratum. For example, the Indiana Urban Interstate system carries 15.20 % of the total traffic (excluding Rural Minor Collectors and Locals) in the state in terms of vehicle-miles traveled. Therefore, 15.20 % of 90 sample sections corresponds to 12 truck-weighing HPMS samples per 3 years or 4 samples a year, for Urban Interstates.

Part 2: Adjustment of site distribution to favor interstates: The FHWA-recommended number of HPMS Truck Weighing Measurements is 90 over a three-year period, with 1/3 of the sample concentrated on the Interstate System (TMG p. 5-2-2). The total number of HPMS truck weighing sites required on interstates, based on their VMT contribution, is 24 (see Appendix B7-2). However, the TMG states that 1/3 of the HPMS truck weighing sample should be concentrated on the Interstate system. Hence the column in Table d(i)-1 that shows the total number of truck weight counts at HPMS sample sections required for each functional class has been revised by first allocating 30 sites to the interstates and then distributing the remaining 60 sites over the remaining functional classes based on their respective VMT contributions.

The forms designed for this analysis are based on the approach described on pages 4-2-1 and 4-2-2 in the *Traffic Monitoring Guide.*

Table B7-d1: Distribution of required number of truck weight counts at HPMS sample sections over a three-year cycle

Sub-stratum	Road Extent (mi)	DVDT 1000's (a)	DVDT (% contribution)	Total # of sites needed over 3-year cycle	Adjusted total
		a	*c = a/b*	*d=c*90*	
Rural Interstates	852.53	17935	12.48	11	**13**
Urban Interstates	319.30	21833	15.20	14	**17**
Urban Other F'ways & Expressways	132.22	2971	2.07	3	**2**
Rural Other Principal Arterials	1699.6	15208	10.59	9	**9**
Urban Other Principal Arterials	1546.8	23740	16.53	15	**14**
Rural Minor Arterial	2246.6	11904	8.29	7	**7**
Urban Minor Arterial	2417.4	16382	11.40	10	**9**
Rural Major Collector	10685	27799	19.35	17	**16**
Urban Collector	2200.4	5881	4.09	4	**3**
Total		143653 = b		90	**90**

Currently, there is no existing regular program to carry out short-term truck weighing measurements. This exercise was begun by INDOT a few years ago, but had to be

abandoned because of problems with the portable weigh-in-motion equipment tried for this purpose. With the purchase of better equipment, this activity has been re-activated by INDOT. As with the HPMS Traffic Volume and Vehicle Classification counts, the recommended program for HPMS Truck Weighing should, as much as possible, incorporate any existing permanent WIM site considered usable for this purpose if it is located within an HPMS section. On the other hand INDOT may choose to locate the site of an HPMS truck-weight sample count near an existing WIM, in order to provide an opportunity to compare count results from the two programs.

Alternative courses of action available to INDOT to generate short-term truck weight data to fulfill possible future HPMS truck-weight reporting requirements

Introduction

The TMG suggests that over a three-year cycle, a total of 90 state-wide short-term truck-weight measurements may be carried out on HPMS sample sections and could be reported to the FHWA. A method for obtaining the distribution of these sites among the various functional classes is described in the *Traffic Monitoring Guide*, and has been implemented elsewhere in this document (see page B7.20). The TMG further states that the specific sites selected for truck weighing measurements should be a subset of the sites already chosen for HPMS vehicle classification measurements. The TMG maintains that the HPMS standard sample (from which the volume, classification and weight samples are successively derived) is guaranteed to have adequate spatial randomness by virtue of its manner of design. As regards temporal randomness, the TMG exhorts states to schedule their HPMS counts in such a way as to capture temporal variations in traffic data.

In the possible event that the reporting of HPMS truck weight data becomes a federal requirement, there are several options available to INDOT to obtain 48-hour truck weight data for such reporting purposes:

a) *No new WIMs or portable counts, only existing WIMs to be used*: INDOT may choose to extract one 48-hour measurement from each of the 33 permanent WIM stations every year, so that about 90 such measurements may be obtained over a three-year period. For this option to be viable, it should be ensured that the distribution of the HPMS truck weight sample is such that the locations of all existing WIMs are accommodated in the sample, i.e. each WIM should lie on an HPMS truck weight sample section.

A disadvantage of this is that the distribution of such a sample may not agree with the desired distribution of the HPMS truck weight sample among the functional classes (page B7.20). Another drawback is that there may be some loss of spatial distribution, since the 90 measurements would be taken from 30 sites instead of 90 different sites.

Merits of this option include a large savings in cost by avoiding any supplemental data collection effort and resources, and the high degree of temporal distribution that is made

available by the large database offered by existing permanent WIM program (short-term data for any part of the entire year can be extracted).

In the *Traffic Monitoring Guide*, the FHWA does not state whether it is permitted for any section to be counted more than once during the three-year period. If such a method were allowed, 48-hour truck weight measurements could be extracted from each existing permanent WIM site annually for three years, to meet the "90 minimum" requirement. Indeed, some small states in New England have resorted to such multiple counts in order to meet this requirement.

Acceptance of such multiple counts would imply acceptance of the extreme scenario, where all the needed number of counts are taken by only one WIM station at various times of the year, i.e., 182 counts (365 days / 48 hours) per year. However, it is clear that, in such a situation, the statistical validity of the HPMS truck-weighing sample would be questionable.

b) *No new portable counts, but increase the number of permanent WIMs*: Another option is to increase the number of permanent WIM stations by about 60, to obtain a total of about 90 WIM sites. This way, one 48-hour truck weight data may be extracted from each of the 90 sites once every three years.

An advantage of this option over Option (a) is that a better measure of spatial distribution would be achieved, since the new WIM sites would be distributed in such a way to achieve an improved spatial distribution. However, this option is clearly not attractive due to the prohibitive cost of implementation.

c) *New portable counts to supplement data from existing WIMs*: This option calls for the establishment of a new program for short-term truck weight measurements using portable equipment to supplement measurements that already made available by the existing WIM stations. About 60 short-term measurements would be needed to supplement 30 measurements from existing WIMs. From the analysis and suggested work schedule shown on page B7d.ii, and Appendix B7d (ii) respectively, 6 sets of portable WIM equipment, staffed by only one crew, are needed for implementing this option. As mentioned on page B7..., the crew responsible for this program would be called upon to work on this activity only 4 times a year, each time lasting for only 5 days. During the times outside this schedule, the crew members may be assigned other duties.

This option is less expensive than (b), but more expensive than (a). It ensures that full utilization is made of existing equipment, in line with the "parsimonious and holistic" approach recommended by the *Traffic Monitoring Guide* for any traffic monitoring activity. It has the advantage of ensuring a better degree of spatial randomness, but has relatively less possibility of better temporal randomness because portable WIM equipment fare poorly in cold weather.

d) *New portable counts, no data retrieved from existing WIMs*: For this option, use is not made of data from existing WIM stations. Instead, this option calls for the establishment of a new program for carrying out 90 short-term truck weigh measurements over a three year period, at different sites and at different periods.

This program could be designed to achieve a better degree of spatial and temporal randomness than option (c), but would be slightly more expensive than that option as the crew would spend more time carrying out the measurements. Even though this option violates the principle of parsimony by not making use of existing equipment, it would make it possible to carry out frequent checks on the accuracy of existing permanent WIMs or short-term truck weight measurements by comparing results from any contiguous permanent and short-term weight sites.
As part of this study, a life cycle cost analysis has been carried out to facilitate the choice of the best option. Details are shown below:

Life cycle cost analysis for various options:
The analysis below provides a framework for analyzing the various options and selecting the most appropriate equipment type (portable vs. Permanent) and quantity. Assumptions for this analysis includes the use of a equipment life cycle period of 10 years, salvage value of 10-15 % for equipment, and an interest rate of 8%.

Option (a), All measurements extracted from existing WIM stations:
No new equipment or staff needed, hence no extra costs incurred.

Option (b), about 60 new permanent WIM equipment to be purchased so that required data may obtained from a total of 90 WIM stations:
b.1 Initial costs
Average cost of 1 set of permanent WIM equipment, 2-lane, Single Load Cell type = \$89,100 (2-lane)
Average cost of 60 sets = \$5,346,000
Assumed rate of replacement = Once in 10 years
Cost of equipment over selected life cycle period = \$6,000,000
Assuming 8% interest rate(i), annualized initial cost of equipment can be found using the "Capital-Recovery" factor used in economic evaluation as follows:

$$= P\,[\,(i.(1+i.)^{n}\,)/\,((1+i.)^{n} - 1)\,]$$
$$= 5{,}346{,}000^{*}\,[\,(0.08^{*}(1+0.08)^{10}\,)/\,((1+0.08)^{10} - 1)\,]$$
$$= \$796{,}663.59$$

b.2 Operating costs
b.2.1 Equipment
Assumed annual cost of maintenance and repairs to each permanent WIM equipment = \$1,000
Hence, annual operating cost for all 60 additional equipment = \$60,000
b.2.2 Staff

7 technicians (average salary \$30,000, assumed) are currently responsible for maintaining about 30 WIMs
Hence 1 WIM equipment requires \$7,000 in terms of staff salary, for maintenance. 60 equipment will require \$420,000 per annum.

Total annual operating costs = \$480,000

b.3 Salvage value
Assuming that after 10 years salvage value is 20% of initial cost.
Salvage value of 60 sets of equipment, S = 60 * 89,100 * 0.2 = \$1,069,200
Assuming interest rate, i = 8%

The annualized salvage value can be found using the "Sinking-Fund Deposit" factor, as follows:

$$(S * i) / [(1+ i.)^n - 1)] = (1,069,200 * 0.08) / [1+0.08)^{10} - 1] = \$73,807.76$$

Total annualized cost for option (b)
= 796,663.59 + 480,000 - 73,807.76 = \$1,350,471.36

Option (c), about 60 counts to be obtained from new portable WIM program to supplement 30 counts from existing permanent WIMs:

c.1 Initial costs
Average cost of 1 set of portable WIM equipment = \$12,000 (see prices in next section). 6 sets are needed (see discussion in previous sections)
Average cost of 6 sets = \$72,000
Assumed rate of replacement = once in 10 years
Assuming 8% interest rate(i), annualized initial cost of equipment can be found using the "Capital-Recovery" factor used in economic evaluation as follows:

$$= P [(i.(1+i.)^n)/ ((1+i.)^n - 1)]$$
$$= 72\,000* [(0.08*(1+0.08)^{10})/ ((1+0.08)^{10} - 1)]$$
$$= \$8,941.24$$

c.2 Operating costs
c.2.1 Equipment
Assumed annual cost of maintenance and repairs to each portable WIM equipment set, including sensor replacement = \$10,000
Hence, annual operating cost for all 6 equipment = \$60,000
c.2.2 Staff
4 technicians (average salary \$30,000) would be responsible for maintaining and operating the 6 portable WIMs
Hence 1 portable WIM equipment requires \$20,000 in terms of staff salary, for

maintenance. 6 equipment would require \$120,000 per annum.
But this crew would use only 30 days in each year (268 working days) on this equipment. Assume 10 additional days for repairs, calibration, etc.
Because 30 out of 268 days will be used for the portable WIM activity, amount required, in terms of staff salary, is \$120,000 * 30/268 = \$13,433

Total operating costs of each portable WIM = \$60,000 + \$13,433 = \$73,433

c.3 Salvage value
Assuming that after 10 years salvage value is 10% of initial cost.
Salvage value of 6 sets of equipment, S = 6 * 12,000 * 0.1 = \$7,200
Assuming interest rate, i = 8%

The annualized salvage value can be found using the "Sinking-Fund Deposit" factor, as follows:

$$(S * i) / [(1+ i.)^n - 1)] = (7{,}200 * 0.08) / [1+0.08)^{10} - 1] = \$414$$

Total annualized cost for option (c) = 8,941.24 + 73,433 - 414.18 = \$89,960.06

Option (d), all 90 counts to be obtained from new portable WIM program

d.1 Initial costs

Average cost of 1 set of portable WIM equipment = \$12,000
Average cost of 6 sets, P, = \$72,000
Assumed rate of replacement = once in 10 years

Assuming 8% interest rate(i), annualized initial cost of equipment can be found using the "Capital-Recovery" factor used in economic evaluation as follows:

$$= P [(i.(1+i.)^n)/ ((1+i.)^n - 1)]$$
$$= 72{,}000* [(0.08*(1+0.08)^{10})/ ((1+0.08)^{10} - 1)]$$
$$= \$8{,}941.24$$

d.2 Operating costs
d.2.1 Equipment
Assumed annual cost of maintenance and repairs to each portable WIM equipment, including sensor replacement = \$20,000
Hence, annual operating cost for all 6 equipment = \$120,000
d.2.2 Staff
4 technicians (average salary \$30,000) would be responsible for maintaining and operating the 6 portable WIMs
Hence 1 portable WIM equipment requires \$20,000 in terms of staff salary, for maintenance. 6 equipment would require \$120,000 per annum.
But this crew would use only 30 out of each year (268 working days) on this equipment. Assume 15 additional days for repairs, calibration, etc.

Because 45 out of 268 days will be used for the portable WIM activity, amount required, in terms of staff salary, is $120,000 * 45/268 = $20,150

Total operating costs of each portable WIM = $48,000 + $20,150 = $68,150

d.3 Salvage value
Assuming that after 10 years salvage value is 5% of initial cost.
Salvage value of 6 sets of equipment, S = 6 * 12,000 * 0.05 = $3,600
Assuming interest rate, i. = 8%

The annualized salvage value can be found using the "Sinking-Fund Deposit" factor, as follows:

$$(S * i) / [(1+i.)^n - 1)] = (3{,}600 * 0.08) / [1+0.08)^{10} - 1] = \$207.08$$

Total annualized cost for option (d) = 8,941.24 + 68,150 + 207.08 = $77,298.32

Table B7-d3: Summarized annual cost structure of each option

	Annualized initial cost	Annual operating cost	Annualized salvage cost	Total annual cost
	a	*b*	*c*	*d = a + b - c*
OPTION A	0	0	0	0
OPTION B	796,663.59	480,000	73,807.76	$1,231,286.57
OPTION C	8,941.24	73,433	414.18	$89,960.06
OPTION D	8,941.24	68,150	207.08	$77,298.32

Selection of best option, and general comments
Option (c) is recommended for selection, from financial and technical considerations. A table showing the summarized annual cost structure of each option is provided as Appendix B7d (iii).

Formulation of work schedule for Option (c)

It should be noted that portable weigh-in-motion measurements are effective only in dry conditions with temperatures above 40 degrees Fahrenheit. From meteorological records in the state of Indiana, number of non-rainy days in a year for which average temperatures at any section of Indiana exceed this threshold is approximately 240.

According to the *AASHTO Guidelines for Traffic Data Programs*, "Portable WIM devices are more difficult to set up and monitor, even if there are self-calibrating features within the device. As a typical value it should be estimated that a two-person WIM team can conduct two 48-hour counts per week if the count sites do not require overnight travel. The typical value identified above will vary from state to state ... Travel time ... influences portable WIM counts .. if travel time is lengthy, productivity of a two-person team can drop to one WIM site a week." As stated in the Guidelines, efficient scheduling of counts is a crucial factor for productivity of employees responsible for such counts.

The following assumptions were the basis for assessing the resources that would be needed for the portable WIM program:

- A typical workday starts at 8:00am and ends at 5:00pm
- A typical workweek is from Monday to Friday
- A suitable crew size for INDOT's portable WIM activities, is 4, consisting of 1 supervisor and 3 technicians
- Transportation to site and installation takes 3 hours
- Every measurement is preceded by testing and/or calibration of the portable WIM equipment, and an average of 1.5 hours is used for such pre-measurement activities
- The duration of measurement is equal to the minimum period recommended by the *Traffic Monitoring Guide* and *AASHTO Guidelines*, for truck-weight short-term counts, i.e., 48 hours
- An average period of 30 minutes is used for equipment removal

With the exception of the first two, all assumptions in the above list were based on information supplied by one of the INDOT contact persons for this data action plan.

The bar chart shown as Appendix B7 d(ii) provides an indication of the ideal schedule to be used by a typical portable WIM team, based on the assumptions made above.

From the bar chart, as many as 6 portable counts may be carried out every week. Since the total number of counts required a year is 24, only four working weeks are needed to complete the counts for the portable WIM program. There are two alternatives by which this can be achieved:

Alternative 1- All work completed in 4 consecutive weeks: This would enable the portable WIM program to be completed very quickly, so that equipment and staff may be re-deployed to special-needs portable WIM counts or other traffic monitoring activities for the rest of the year. However, it is desired that the portable WIM program be characterized by an even spatial and temporal distribution. Carrying out all the

measurements in 4 consecutive weeks may preclude travel all over the state by the team and would therefore yield truck weight patterns for only a restricted geographical region of the state. Furthermore, data for only 1 month would be available and it is unlikely that this would adequately reflect true truck weight patterns.

This alternative is clearly not attractive, because its associated benefits are outweighed by the need for monitoring truck weight data from a spatial and temporal standpoint.

Alternative 2- Four sets of week-long portable WIM measurements spaced out over the entire "usable" year: A "set" consists of one week's worth of work, i.e., measurements at 6 different sites. A "usable" year consists of 240 days, during which weather conditions all over the state are expected to be suitable for the portable WIM program.

This means that a set of measurements may be carried out every 60 days, i.e., every 2 months, within the 240-day period. This schedule would allow truck weights at all geographical regions and functional classes to be monitored. Also, the 4 sets of measurements may be spaced out as much as possible over the usable year in order to achieve a fair temporal distribution of the measurements.

The crew responsible for the portable WIM program would be called upon for this program 4 times a year, each time for only 5 working days. During the periods outside of this schedule, such staff could be assigned other duties.

Resource requirements for Option (c), alternative 2

Personnel:
The composition of the crew (and required salaries) needed to implement the portable WIM program is as follows:

- 1 traffic data collection supervisor ($40,000 p.a)
- 3 technicians ($30,000 p.a.)

Equipment:
Currently there are four major manufacturers of portable WIM equipment:

1) PEEK Traffic Monitoring Equipment, based in Sarasota, Florida
2) International Road Dynamics, based in Ontario, Canada
3) PAT Equipment, based in Germany
4) International Traffic Corporation, based in Spring Grove, Illinois

A discussion of the prices and features of the equipment manufactured by these companies is provided below. At the time of reporting, there had been no response from PAT technologies to a request for their equipment description and pricing.

Description of various current brands and types of portable WIM equipment
Portable weigh-in-motion systems are designed to be used on a temporary basis then removed and used elsewhere. It is therefore expected that such equipment should be

robust and capable of withstanding the wear and tear associated with frequent installation and removal. Brief descriptions of some portable WIM systems that are currently available on the market are provided below, while further details on such equipment can be found in Addendum 1 (Equipment file) of the main report.

1. *TEL-WIM, manufactured by International Traffic Corporation*
TEL-WIM is a versatile weigh-in-motion system used for multi-lane data collection in portable and permanent applications. The TEL-WIM system consists of a processing rack enclosed in painted cast aluminum metal card cage, a pavement-installed combination of inductive loops and sensors, and an integrated keyboard and LCD display with serial link to a computer or modem. The portable TEL-WIM system can use a different number of sensors, such as capacitance mats and piezoelectric sensors. The Class 1 piezo system is very cost effective, but the capacitance mat system offers higher accuracy weighings. The communications and processing software for TEL's weigh-in-motion systems has many features. While on line with the field unit the TELCOM software allows viewing of traffic data in many different configurations including axle-by-axle modes and per-vehicle modes. According to the product catalog, all FHWA and TMG formats are included in the reporting system, and reporting formats can also be customized to meet specific needs.
ITC's products are warranted against defects in workmanship and materials for a period of one year. Prices of various components and accessories are shown below:

Description	Price (April 1997)
TEL-WIM 2-lane mat	$9,300
TEL-WIM 2-lane piezo	$10,900
TEL-WIM 4-lane mat	$10,300
TEL-WIM 4-lane piezo	$11,900
Capacitance mat	$10,000
TEL weather-proof case	$1,700
Tel cables	$75
WIM software	$2,000
WIM software remote	$5000
Battery charger	&295

Total = $20,000 approx.

2. *ADR-2000, manufactured by Peek Traffic, Inc.*
The ADR-2000 is a portable and weather-proof system that is often used for vehicle counting and classification. Installing a P-WIM card in the ADR-2000 enables it to emulate the dynamic weigh-bridge method of weighing heavy commercial vehicles at high speeds while retaining the full functionality and ease of use of the ADR-2000 as a counter/classifier. The product catalog states that where short-term data are required, temporary stick-down sensors may be installed for cost effective measurements. Site monitoring includes a 4-lane capability on the ADR-2000, and an 8-lane capability on the ADR-3000 range. Power is provided by a battery, but is capable of solar or line power back-up. The catalog states that the modular design of this equipment facilitates flexibility of installation to suit specific site demands. Data from the ADRs may be

handled by the VISA WIM Data Analysis Software. This presents data in a per-vehicle mode as well as a 70-bin tabulated format per lane. Data conversion to Lotus-compatible worksheets is fully supported to aid fast and professional production of detailed graphical displays. Peek Traffic Inc. warrants their products against manufacturing defects in materials and workmanship for one year from date of shipment from the Peek factory. Prices of various components and accessories of the ADR-2000 are shown below:

Description	Price (October 13, 1997)
1 Portable 1-lane WIM system, including the following items: - ADR-2000KD/SL0RT/4W/PCM data recorder - Internal 6-volt battery - Solar panel in lid - Internal temperature sensor - WIM card with input harnesses - 4 MB and RAM memory card - 2 piezo sensors, 12' long with 100' coax, BL type - 60' roll of Mar-mac tape - AWACS and TDP software	$13, 995
2. Additional piezo sensors	$1,088
3. Tape	$92

3. *IRD 1070 portable WIM system, manufactured by International Road Dynamics.*
The IRD Model 1070 portable WIM is a robust and compact unit that is relatively easy to carry from site to site. It may be fitted into a cabinet or secured by lock and chain to a suitable structure, such as a utility pole. According to the product catalog, this system can be set up in a few minutes, and then easily disconnected when the user is ready to move to another site. This model utilizes modular interface cards, and can therefore be adapted for use by both portable and permanent sensors. The system is capable of real time display of traffic in both graphical and text formats. It is capable of over 24 hours of continuous operation with standard internal battery pack. However, there is an external connection for charging and/or uninterrupted operation via AC, DC or solar power. It is capable of monitoring up to 4 lanes. Standard reports include weights of various axles, gross vehicle weight, class by hour and day, Equivalent Single Axle Loads, weight violations, etc. A optional IRD WIMGRAPH and software package, which provides report generation and presentation, is also available.
IRD provides a standard one year warranty for its equipment.

Prices of the IRD 1070 Portable WIM system and various sensor types are shown below:

Description	Price (October 6, 1997)
1 1070 Portable WIM Electronics *1	$9,900
2. Various sensor types a) AMP BL CL II 12' portable sensor b) Model AS470 Phillips 1mm Piezoelectric c) Model AS500 Phillips 3mm CL I, Piezoelectric d) Model AS480 Phillips 8mm Piezoelectric	$530 $267 $1,350 $1,121

*1: Includes hardware and standard IRD software.

E. CURRENT ISSUES WITH THE HPMS PROGRAM

E.1 Nesting of Operations: Issues and Implications

In line with TMG procedures, sites for HPMS vehicle classification are taken from the set of sites in the HPMS traffic volume sample. However, vehicle classification equipment also provides data on traffic volumes. Hence it may not be necessary to carry out separate traffic volume counts at vehicle classification sites. Similarly, sites for truck weighing should be taken from the set of sites for vehicle classification. Truck weighing equipment provides data on classification and volumes, hence it may not be necessary to conduct separate counts for traffic volumes and vehicle classification at truck weighing sites.

Such advantages offered by these nested operations make it possible for INDOT to save resources in the overall data collection effort.

However, under some circumstances, the desire to economize may be outweighed by a need to compare data at a site measured separately by different equipment, e.g., comparison of vehicle classification obtained by classification equipment and that obtained by truck weighing equipment. Nested counts therefore provide an opportunity for economy as well as data editing.

E.2 STRATEGIC REASSESSMENT OF HPMS PROGRAM BY FHWA

FHWA Docket N°. 97-10 issued by the FHWA of the US DOT and published in the December 23, 1996 issue of the *Federal Register* (vol. 61 N°. 247) provides an indication of a possible strategic reassessment of the HPMS, and solicits public comments on the conceptual plan for such reassessment.

The notice states that the purpose of the proposed strategic reassessment is to review the HPMS in light of contemporary issues and anticipated future needs, and to determine what changes, if any, are necessary at this time. According to the notice, contemporary issues and future needs include changing technology such as Intelligent Transportation Systems (ITS), Geographical Information Systems (GIS), the Government Performance

and Results Act (GPRA), and changing data needs of States including increased use of the management systems. A tentative list of the options under consideration, at the time of the publication, is attached on the following page.

To date, the final decision on the strategic reassessment has not been reached. It is envisaged that any changes to the existing HPMS program will have far reaching consequences on the nature and scope of data collection and analysis needs.

It seems therefore prudent that the recommendations offered in this document for the Indiana HPMS data collection program be considered in light of a possible strategic reassessment of the national HPMS program.

Options for Strategic Reassessment of HPMS Program

N°.	Option	Description
1	Incremental change	- Eliminate/streamline/update data items. - Revise sampling rates and required data collection intervals. - Minimize non-NHS data reporting requirements. - Reassess data needs for models and area-wide reports.
2	NHS only	- Restrict HPMS requirements to the NHS.
2a	NHS and other roads	- Collect basic inventory and performance data on all roads. - Restrict detailed HPMS data requirements to the NHS.
2b	NHS and other arterials	- Restrict HPMS requirements to the NHS and all Other Principal Arterials.
2c	NHS and State roads	- Restrict HPMS requirements to the NHS and the non-NHS roads on State systems.
3	National Sample	- Collect HPMS data for a nationally significant sample only. - State significant HPMS data collection is optional.
3a	National/State sample	- Collect basic inventory and performance data on all roads. - Collect national level sample for remaining HPMS data.
3b	National/State sample	- Collect basic inventory and performance data on all roads. - Collect State significant sample data for the NHS and for meeting EPA travel requirements. - Collect national level sample for non-NHS data.
3c,d	Contract data collection	- Collect national level sample data by private contract. - Collect national level sample data by State contract. - Pay States specifically to collect required data.
4	Other sources	- Retain HPMS for most existing data. - Obtain supplemental data from alternate sources: * systems operation data * transportation plans * transportation improvement programs * case studies * contract collection
5	Little or no change	Retain HPMS essentially unchanged.

F. ESTIMATION OF FUTURE HPMS SAMPLE SIZES

The size of the HPMS standard sample is a function of the variability of data within each volume group. In accordance with recommendations made in the *HPMS Field Manual*, the required size of the standard sample should be revised each year based on the most current AADT estimates. Because the annual sample size for HPMS traffic volume is one-third that of the standard sample, such revisions would automatically apply to the HPMS traffic volume sample size.

The sample sizes of 300 and 90 for HPMS vehicle classification and truck weights, respectively, are based on a preliminary analysis of a selected representative state's data by the FHWA. The *Traffic Monitoring Guide* recommends that this sample size may be revised for each state using its own data, and offers procedures for such estimation. INDOT may therefore carry out analysis of its data to arrive at its own unique sample sizes for HPMS classification and truck weight.

Finally, it is important to note that these and any other recommendations made in this data action plan are to be considered tentative, pending the outcome of FHWA's strategic re-assessment of the HPMS program.

DRAFT TMS/H Data Action Plan **C**
Continuous Count Program
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September 21, 1998

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INDOT Work Plan Activity: Verification of adequacy/accuracy and locations of existing continuous traffic monitoring equipment as related to vehicle volumes, weights and classifications

23 CFR Chapter 1, Subchapter F (Transportation and Infrastructure Management), Part 500 (Management and Monitoring Systems), Subpart H (Traffic Monitoring System for Highways) Section 500.807(c) *Federal Register*, 1 December 1993, p. 63484: " Within each State, there shall be sufficient continuous counters of traffic volumes, vehicle classifications, and vehicle weights to provide estimates of changes in highway travel patterns and to provide for the development of day-of-week, seasonal, axle correction, growth factors or other comparable factors approved by the FHWA that support the development of traffic estimates to meet the statistical requirements of data uses ... As appropriate, sufficient continuous count of vehicle classification and vehicle weight shall be available to address traffic data program needs."

A. TRAFFIC DATA NEEDS :

1. **Type of data required:**
   - Traffic volumes (MADT and AADT at ATR sites, for development of adjustment factors for statewide AADT estimation)
   - Vehicle classification (% of vehicles in Class 4 and above)
   - Vehicle weight (ESALs for pavement design)

2. **Number of sites required** for each data type: As determined by statistical analysis. The number of ATR sites in each seasonal factor group should be enough to achieve desired minimum precision values for collected data.

3. **Location (distribution) of sites**: Representative distribution of total required number of sites among the various seasonal factor groups, with emphasis on NHS segments, geographical location, and other relevant factors.

4. **Frequency and duration of counts**: 24 hours a day, 365 days a year.

From p. 3-2-1 of the *Traffic Monitoring Guide*, and from p. 57 of the *AASHTO Guide for Traffic Data Programs*, **development of seasonal factors to expand short term counts**

to annual average daily traffic (AADT) is a primary objective of the continuous ATR program and the one that should guide the establishment of sample size.
The ATR program is also used in the generation of growth factors. Also, data reported to the FHWA for monthly publication of Traffic Volume Trend Reports (see TMG p. 3-2-2) are generated by ATR equipment.

B. THE EXISTING SITUATION
According to the *Traffic Monitoring Guide,* page 3-2-2, "the first step in reviewing any ATR program is to define, analyze and document the existing situation, because a clear understanding of the present program will increase confidence placed on later decisions to modify the program." The TMG further recommends that such a review should explore the historical design, procedures, equipment, personnel and uses of information.

1. Historical design of INDOT's ATR program
The ATR program in the state of Indiana was established by INDOT about two decades ago, with the primary objective of generating traffic data for reporting to the FWHA. At that time, about 55 volume-counting Telemetry ATR stations were installed. The nature of the distribution of these Telemetry stations was governed by a desire to ensure fair geographical representation. Hence consideration was not specifically given to precision requirements.

In the year 1984, weigh-in-motion (WIM) equipment, manufactured by International Road Dynamics (IRD), was installed at various sites throughout the state. The selection of sites for this equipment was based on a variety of factors, such as :
a) existing locations: sites of old telemetry equipment represented considerable investment. To avoid extra costs associated with establishing new sites, some of these old sites were upgraded with the new WIM equipment.
b) fair distribution over geographical areas of the state (the state was divided into three regions for this purpose).
c) sites of interest to the Strategic Highway Research Project (SHRP), out of which has evolved the Long Term Pavement Performance (LTPP) program.
d) pavement types and border locations: according to INDOT, about 1/2 of the 33 permanent WIM sites were located such that a variety of pavement types were represented, and also to capture truck weight patterns at major points of entry.

There are indications that about a decade ago, a study was carried out to include the consideration of precision requirements as the state's ATR equipment were being located. However no documentation on such a study has yet been found.

In the last couple of years, about 4 new Telemetry ATR stations have been established, including the cluster of ATRs around the Bloomington area. Also, about 5 Telemetry stations have been upgraded to WIM sites and can therefore monitor classification and truck weights in addition to volumes. These sites have been indicated in Appendix 1.

The continuous count program currently consists of 92 ATR sites (of which 34 have WIM equipment and 58 have Telemetry equipment). The location of these sites are shown on the map attached as Figure C-1(a).

The process of evaluating ATR sites, for each count type, should be repeated every year in order to monitor the performance of the program and to carry out any updates if necessary. INDOT has indicated that upgrading of some Telemetry sites to classification status is in progress. It is expected that the outcome of this upgrading exercise would be given due consideration in any future evaluation of the state's ATR program.

2. Data collection equipment and procedures.

Equipment at each WIM site consists of axle sensors, steel plates and inductive loops embedded in the road surface as vehicle detectors. This equipment continuously collects data on traffic volumes, vehicle classification and vehicle loads. The collected data are transmitted automatically to the data processing center at the INDOT main office in Indianapolis through standard dial-up lines, on a daily basis.

Equipment at Telemetry sites are permanent traffic counters that use a single inductive loop to detect vehicle presence. This equipment, manufactured by Streeter Richardson Inc. and installed in 1985, continuously collects traffic volume data at these sites. Like the WIM sites, Telemetry sites transmit data through dial-up lines to the traffic data processing center at the INDOT main office in Indianapolis.

Details of equipment at each site are shown in the table attached as Appendix 1 of the main report.

3. Staff for data collection and analysis

Lists of personnel involved in data collection and analysis of continuous count data are shown in the tables in Appendices 2 and 4 of the main report, respectively.

C. EVALUATION OF THE EXISTING SITUATION

Currently, traffic volume data are collected at all 92 ATR sites, subject to equipment malfunction. Data on vehicle classification and vehicle loads are collected at 34 of these ATR sites. Some of this equipment, particularly the WIMs, have had a rather high downtime rate in previous years, but have seen a sharp improvement in the last year due to increased vigilance and prompt attention currently given by INDOT field staff to this equipment.

This equipment collects data 24 hours a day and 365 days a year. These, respectively, are the required frequency and duration for the continuous count program.

The main question for the Continuous Count program, for which this data action plan seeks to address is the selection of the best seasonal grouping criterion (and

corresponding seasonal groupings), assessment of the adequacy of existing sites and appropriate distribution of any additional sites.

There are three sub-programs within the Continuous Count program: the traffic volume, vehicle classification, and truck weighing programs. The analysis has been carried separately for each, but the final results has been evaluated such that a common recommendation is made for the overall structure of the Continuous Count program. A flow chart to illustrate the various stages of work for this study is shown on the following page.

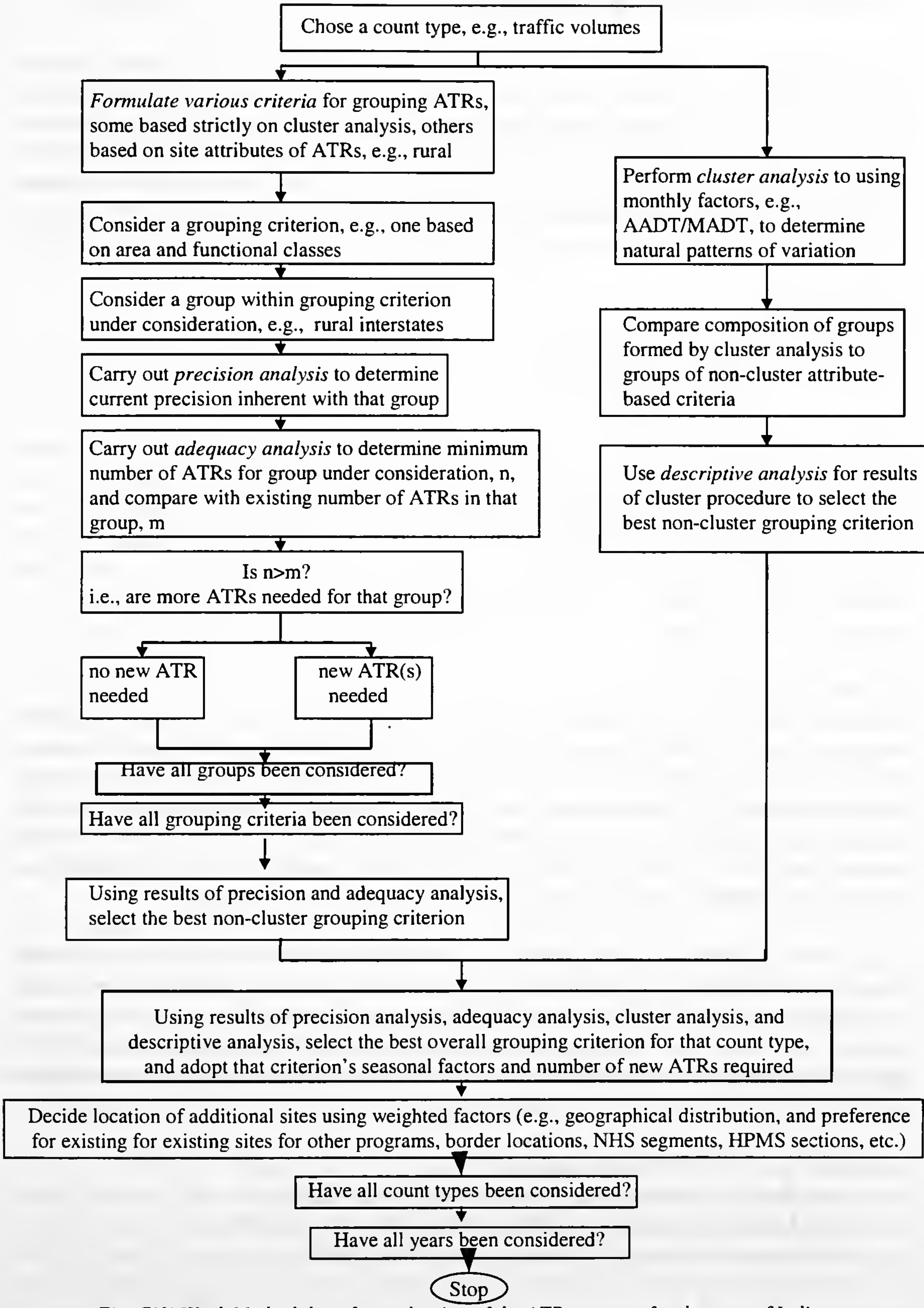


Fig. C(1) Work Methodology for evaluation of the ATR program for the state of Indiana

Description of Stages of Work Methodology

(a) Year of Study

For traffic volume ATRs, the study was carried out using data that were collected in 1995. However, for the vehicle classification and truck weight aspects of the study, only portions of 1995 data were available. It is desirable to use data from several years, instead of one, for the analysis, in order to assess the consistency of the clusters formed from year to year and to examine the uniformity of the coefficients of variation for each seasonal group within each grouping criterion, from year to year.

(b) Count Types

The study was carried out for each of the following three count types:

- traffic volumes
- vehicle classification
- truck weights.

Other count types, such as speed, vehicle occupancy and directional distribution, were not studied. The *AASHTO Guidelines for Traffic Data Programs* states that grouping of data collection sites for truck weighing and vehicle classification may be carried out in a fashion similar to that used for traffic volumes. However, the Guidelines caution that the composition of groups for classification and weights may or may not be the same as that for traffic volumes. Therefore the entire procedure was carried out for all three count types under consideration.

(c) Cluster Analysis

Cluster analysis is a statistical method used to group observations into clusters such that within each cluster there is minimum variation of the data values, and between clusters there is maximum variation. Cluster analysis is the method suggested by the *Traffic Monitoring Guide* for corroborating (or rejecting) existing seasonal groups used by various States. It has been used by several states, such as Kansas, to arrive at a valid seasonal group list, not only for annualizing short-term counts, but also for determining the minimum number of sites needed to achieve a target level of precision.

In this study, 12-dimensional clustering will be carried out because there are 12 monthly factors for each observation (ATR station). Because cluster analysis groups observations on the basis of the natural patterns of their variations, the acceptability of each grouping criterion will be assessed using cluster analysis. Unacceptable grouping criteria will be identified by very poor precision values and lack of appreciable agreement with the natural grouping obtained through cluster analysis.

The variables used in the cluster analysis are:

For Traffic Volume ATRs - ratio of MADT to AADT
For Vehicle-Classification ATRs - ratio of MAPT to AAPT
For Truck-Weight ATRs - ratio of MATW to AATW

MA - Monthly average, AA - Annual average , DT - daily traffic

DT - daily traffic, PT - percentage trucks, TW - truck weights.

Before performing cluster analysis on the coordinate data units, it was necessary to consider scaling or transforming the variables. Because variables with large variances tend to have more effect on the resulting clusters than those with small variances. The cluster procedure is very sensitive to outliers. Therefore, the monthly factors (ratio of average monthly data to average annual volumes) rather than the raw monthly averages, were used for the clustering. Outlying data values were identified and excluded from the analysis. Such outlying values are often attributable to equipment malfunction, diversion due to road construction, and atypical traffic conditions.

The *Traffic Monitoring Guide* of the Federal Highway Administration states that "the cluster analysis [should be] carried out using the monthly factors", rather than the raw monthly characteristics, otherwise "the [value] differences will affect cluster formation". Such data transformation changes the numbers used for clustering, but does not really change the pattern of variation.

The method used in clustering is Ward's Minimum-Variance method. Results of the cluster analysis for the three count types are provided as Appendices C-1.3, C-2.3 and C-3.3.

(c).1 Interpretation of the results of the cluster procedure

In any group formed by the cluster procedure, the dominant site attribute in the group was identified as a basis for determining how well non-cluster grouping criteria fits those offered by cluster analysis. The results of cluster analysis are generally adequate to detect patterns of traffic characteristics for the state but are insufficient for a complete determination of how many seasonal groups should be formed. This is because the cluster analysis does not provide a consistent criterion for assignment of short-term counts to any group. As recommended in the *Traffic Monitoring Guide*, it is therefore necessary to carry out descriptive analysis of the ATR data.

(d) Formulation of criteria for grouping of ATR sites

As stated in the *Traffic Monitoring Guide*, the nature of grouping varies from state to state. The Guide suggests that, for each state, various grouping criteria should be examined to determine the one that best addresses the traffic patterns in the state and that is best corroborated by the cluster and precision analyses.

In this study the following attributes were used to formulate criteria used in grouping of ATR sites:

- functional classification of roads on which sites are located, e.g., interstate, minor collector. The functional class of roads on which ATRs lie is the most common attribute used by states to establish their grouping criteria and consequent seasonal group lists. It is likely that traffic volume, classification and weight patterns would differ from one functional class to another. Indeed, many researchers, such as Hallenbeck and Ritchie, have confirmed that traffic patterns in any state depend on the road classification.

For example, the seasonal variation of traffic volumes on various Interstate roads has been found to be similar, but markedly different from that on collectors and locals. However, as these researchers have found out, these patterns are more readily observed when the functional classification is combined with other attributes, such as area classification, and various combinations have been adopted by many states.

- area location of ATR sites, e.g., rural, urban. A "rural" area is defined by the HPMS Field Manual as any area having a population of less than 50,000, while areas with population exceeding this figure are designated as "urban" areas. Considering that the land use of areas adjacent to urban roads is usually not the same as that for rural roads, it is expected that the seasonal variation of traffic volumes for these two area types would be significantly different.

- regional location of sites, e.g., Northern Indiana, Southwestern Indiana. Notwithstanding the rural/urban attributes, it is possible that the regional location of a road may provide an indication of the type and seasonality of traffic that uses the road. An urban interstate road located at northwestern Indiana may have different traffic patterns from a road in Indianapolis having the same functional and area class. Such regional bias, however, is quite difficult to detect, and has not been considered by many states.

- peripheral location of the ATRs, i.e., whether the ATR is located in a county that has a state border. This attribute was considered in the analysis because it is believed that traffic patterns on roads leading out of the state or located near the state boundaries may have somewhat different traffic patterns from those that are located far from the boundaries.

Based on the attributes described above, the various criteria formulated are as follows:

Criterion A- ATRs placed in groups strictly on the basis on the results of the Cluster analysis, in which the number of groups was not specifically entered as an input parameter.

Criterion B- ATRs placed in groups strictly on the basis on the results of the Cluster analysis, in which the number of groups was entered as an input parameter.

Criterion C (Grouping based on current INDOT group list)
The current INDOT group list is the current list being used by INDOT for grouping of ATR sites for annualization of 48-hour counts, application of growth factors and other analyses that involve grouping. This group list is as follows:

Group 1: Urban Interstates, Freeways and Expressways
Group 2: Urban Principal Arterials, Minor Arterials, Collectors, and Locals
Group 3: Rural Interstates
Group 4: Rural Principal Arterials and Minor Arterials
Group 5: Rural Collectors and Locals

Criterion D (Grouping based on FHWA's HPMS classes)
The "new" FHWA classes are the classes provided in Appendix G of the *HPMS Field Manual*, for reporting of data for the nationwide Highway Performance Monitoring System (HPMS). Some researchers have advocated the grouping of ATR data using this grouping criterion. It is therefore necessary to investigate the implications of adopting such a criterion. This criterion's group list is as follows:

Group 1: Rural Interstates
Group 2: Urban Interstates
Group 3: Urban Freeways and Expressways
Group 4: Rural Principal Arterials
Group 5: Rural Minor Arterials
Group 6: Rural Collectors and Locals
Group 7: Urban Principal Arterials
Group 8: Urban Minor Arterials
Group 9: Urban Collectors and Locals

Criterion F (Grouping based on a combination of area and functional classes)
Some states, such as Kansas, have found that traffic patterns on their roads are adequately captured using a combination of area and functional classes as follows:

Group 1: Rural Interstates and Other Principal Arterials
Group 2: Rural Other, i.e., Minor Arterials, Major and Minor Collectors, Locals.
Group 3: Urban Interstates, Other Principal Arterials, and Freeways and Expressways.
Group 4: Urban Other, i.e., Minor Arterials, Major and Minor Collectors, Locals.

Criterion G (Grouping based on functional classes only)
This grouping criterion was used to determine whether traffic volume patterns can be considered independent of area class, regional class and peripheral class, and are only significantly influenced by road functional class. The following grouping list was used for the analysis:

Group 1: Interstates, Freeways and Expressways
Group 2: Other Principal Arterials
Group 3: Minor Arterials
Group 4: Collectors and Locals

Criterion H (Grouping based on regional and functional classes)
The *AASHTO Guidelines for Traffic Data Programs* suggests that some states may be able to detect regional patterns in their traffic data. This grouping criterion is characterized by ATRs grouped on the basis of their regional locations (north versus south), and their functional classes, i.e., high class roads versus lower road classes. A list of the groups for this criterion is shown below:

Group 1: Northern Interstates, Freeways and Expressways
Group 2: Northern Other
Group 3: Southern Interstates, Freeways and Expressways
Group 4: Southern Other

Criterion I (Grouping based on peripheral and functional classes)
The possibility that traffic patterns at or near the state borders differs from patterns in the inner parts of the state, was examined as part of this study. For this investigation, the following group list was formulated and analyzed:

Group 1: Peripheral Interstates
Group 2: Non-peripheral Interstates
Group 3: Peripheral Other
Group 4: Non-peripheral Other

Criterion J (Grouping based only on regional locations)
The state of Indiana has a somewhat regular geometrical shape, with each region being somewhat unique in its characteristics. It is probable that the traffic patterns across the state may not be adequately captured by a mere rural/urban classification. It may be possible to detect distinct patterns within regional areas grouped as shown below:

Group 1: Northwestern
Group 2: Northeastern
Group 3: Southwestern
Group 4: Southeastern
Group 5: Central

(e) Precision Analysis of ATR data
The results of cluster analysis are generally adequate to detect patterns of traffic characteristics for the state but are insufficient for a complete determination of how many seasonal groups should be formed. This is because the cluster analysis does not provide a consistent criterion for assignment of short-term counts to any group. As recommended in the *Traffic Monitoring Guide*, it is therefore necessary to follow the cluster procedure with descriptive analysis of the ATR data. This involves the examination of the clusters formed to determine whether any anomalous pattern is present, explaining such anomalous behavior, if any, and deleting existing groups (or forming new ones) if needed.

Precision analysis involves examining the precision of ATR data for each seasonal group, using the criterion under consideration. Precision values of large magnitude are indicative of high variability of data units within the seasonal group and reflects a "poor fit". Precision values well below the threshold, i.e., 10%, generally reflect a "well-formed" group which exhibits relatively little variation between the data units generated by ATRs in that group.

The precision interval is

$$D = T_{1-d/2,\, n-1} * C/n^{0.5} \qquad (3)$$

where

D = precision interval as a proportion or percentage of the mean and
C = coefficient of variation of the factors.

(f) Adequacy analysis (determination of minimum number of sites for each seasonal group)
After the results of the cluster and precision analyses had been studied, the relevant interpretations made, the appropriate seasonal groups established, and allocation of existing ATR locations to those groups carried out, the next step was to determine the number of locations needed to achieve the desired precision level for each seasonal group. To carry out this task, statistical sampling procedures were used. Because the continuous ATR locations in INDOT's current continuous count program were randomly distributed, certain assumptions were made. The basic assumption made in the procedure is that the existing locations are equivalent to a simple random sample selection (pseudo-random assumption). Once this assumption is made, the normal distribution theory provides the appropriate methodology.

The standard equation for estimating the confidence intervals for a simple random sample is:

$$B = X +/- T_{1-d/2,\, n-1} \qquad (1)$$

where

B = upper and lower boundaries of the confidence interval,
X = mean factor,
T = value of Student's T distribution with 1-d/2 level of confidence and n-1 degrees of freedom,
n = number of ATR locations within the seasonal group,
d = significance level, and
s = standard deviation of the factors.

The precision interval is

$$D = T_{1-d/2,\, n-1} * S/n^{0.5} \qquad (2)$$

where

D = absolute precision interval,
S = standard deviation of the factors.

The coefficient of variation is the ratio of the standard deviation to the mean, hence the equation can be simplified to express the interval as a proportion or a percentage of the estimate.

Therefore, the equation becomes:

$$D = T_{1-d/2,\,n-1} * C/n^{0.5} \quad (3)$$

where

D = precision interval as a proportion or percentage of the mean and
C = coefficient of variation of the factors.

A percentage is equal to a proportion times 100, i.e., 10 percent is equivalent to a proportion of 1/10.

Iterative use of equation (3) makes it possible to estimate the sample size, n, needed to achieve any desired precision intervals or confidence levels. According to the *Traffic Monitoring Guide*, specifying the level of precision desired can be a very difficult undertaking, because very loose precision reduces the usefulness of the data for decision-making purposes. On the other hand, tight precision translates to very large numbers of ATR stations, an option that may not be economically feasible. According to the *Traffic Monitoring Guide*, traffic estimates of this nature have traditionally been thought of as having a precision of ± 10 percent. A precision of 10 percent can be established with a high confidence level or a low confidence level. The higher the confidence level desired, the larger the sample size needed to achieve that confidence level. Furthermore, the precision requirement could be applied individually to each seasonal group or to an aggregate statewide estimate based on more complex stratified random sampling procedures.

The reliability levels recommended in the *Traffic Monitoring Guide* are 10 percent precision with 95 percent confidence, or "95-10", for each individual seasonal group, excluding recreational groups, where no precision requirement is specified. The meaning of this precision requirement is that, out of every 100 traffic measurements, 95 are expected to fall within of ± 10 % of the true value.

As was suggested by Faghri, Glaubitz, and Parameswaran, in their paper titled *"Development of a Traffic Monitoring System for the State of Delaware"*, seasonal factor groups for which there are no existing ATRs (and thus do not have any data available for statistical estimation of the number of ATRs required), should be assigned a small number of ATR sites for the first year of data collection.

C.5 Selection of "best" grouping criterion and corresponding group list.

The acceptability of each grouping criterion was assessed using the results of the precision analysis, for the count type, and for the year in question. Unacceptable grouping criteria were identified by very poor precision values and lack of appreciable agreement with the natural grouping obtained through cluster analysis.

The best grouping criterion is that which . . .

(i) has least variation within its data values (as evidenced by the least coefficients of variation),

(ii) has groups and group compositions that most closely resemble that of the natural cluster groupings,

(iii) provides a grouping list and associated factors that permit annualization of short-term counts, and

(iv) would not involve excessive cost to implement.

An adjustment factor of 30% has been applied to the number of needed classification and weight ATR sites to cover the relatively high downtime rates of INDOT's bending plate WIM equipment which constitute a majority of such WIM equipment. The percentage of piezoelectric WIM equipment in INDOT's inventory has grown significantly over the past few years. Piezoelectric WIM equipment generally have higher downtime rates than the bending plate type. The type and brand of WIM equipment that has one of the least downtime rates is the Single Load Cell WIM, manufactured by International Road Dynamics (IRD). The price of the Single Load Cell WIM equipment is far exceeds prices of other types of WIM equipment.

(g) Suggestions for Modifying Distribution of ATRs

(g).1 When needed sites are fewer than existing sites

Once the number of groups and locations per group are established, the existing program must be modified. The first step is to distribute the existing locations according to the defined groups. The *Traffic Monitoring Guide* states that, in general, from 5 to 8 locations are needed in each of the 5 groups, usually resulting in a total of 30 to 40 locations in a State. The Guide concedes that exceptions to this rule of thumb are expected but because the procedures are directly driven by the analysis of each State's data, the results will be justifiable and directly applicable to each State.

If the distribution of existing locations results in a surplus of locations for a group, then redundant locations are candidates for discontinuation. If the surplus is large, the *Traffic Monitoring Guide* recommends that reduction should be planned in stages and after adequate analysis to ensure that the cuts do not affect reliability in unexpected ways. For example, if 12 locations exist and six are needed, then the reduction may be carried out by discontinuing 2 locations annually over a period of 3 years.

The *Traffic Monitoring Guide* cautions that ATR removals should be carefully thought out. Maintaining a few additional surplus locations would help to supplement the groups and to compensate for equipment downtime or missing data problems. If the distribution of present locations results in a shortage of locations, then additional locations should be selected and added to the group.

Factors to consider in the decision to discontinue a site from the continuous ATR program are:

1. Other uses of existing information or importance assigned to sites-- As mentioned before, determination of seasonal groups and their factors is not the only objective of continuous ATR data. Therefore other factors should be considered before a decision is made to discontinue an ATR site. One of such factors is the general reliability of data: More ATR locations mean greater reliability of data.

2. Quality of the traffic data-- Permanent counter data is subject to many discontinuities due to equipment downtime, resulting in missing data, and to the vagaries of data editing and imputation. Equipment that persistently generates unreliable or no data for any reason can be considered for termination.

(g).2 When needed sites exceed existing sites (Distribution of additional ATR sites needed).
Phase 1 (Recommendations from this study):
For each count type and for each seasonal group (which includes functional class) in each count type, factors that will be considered in the decision to locate additional ATR sites are:

1. Location on NHS road segment
2. Proximity to state borders
3. Location on HPMS sample section
4. Distribution over geographical areas of the state
5. Existing sites used for other count programs (possibility of upgrading)

Phase 2 (General review of recommended site locations, and determination of exact field position of additional ATRs):
Sometimes, engineering judgment is necessary to confirm the distribution and geographical location of additional ATR sites, in order to fulfill extraneous or peculiar in-house traffic data needs.

Furthermore, any location that is selected for an additional ATR needs to be confirmed, at the implementation stage, by INDOT field technicians who are trained in selection of exact locations for ATR stations. This means that the final site of installation may deviate from the originally recommended site by a few meters or hundreds of meters, in order to avoid curves, areas of deteriorated pavement, and other areas with unsuitable site conditions. It is not expected that such minor shifts would constitute a significant departure from the original recommendations.

Discussion of Phase 1 factors:

1. *Location on National Highway System (NHS) segment*: The NHS is a network of roads selected for their strategic importance to the nation's economy and defense. Monitoring of traffic on the NHS is of major concern to the federal and state governments, and recent legislation on traffic monitoring activities have largely focused on the NHS. Potential ATR sites that lie on NHS segments, therefore are made to have greater chances of selection.

2. *Proximity to state borders*: Appropriately nicknamed " The Crossroads State", the State of Indiana has significant volume of overall and truck traffic across is borders. Traffic patterns on major highways that lead out of the state are vital for purposes of state highway planning and legislation. Many state highway agencies consider proximity to state borders a paramount factor in the decision to locate ATR stations. This study will

therefore consider the possible location of additional ATRs at sites that are not only near the state border, but also lie on a major road leading out of the state.

3. *Location on HPMS sample section*: The HPMS is a nation-wide inventory system that assesses operating characteristics (such as volumes, classification and weights) of highway infrastructure, and serves highway data needs to support the functions of the FHWA. According to the *Traffic Monitoring Guide*, locating additional ATR sites at or near HPMS sites should be given priority. This would enhance integration of the continuous and coverage count programs.

4. *Distribution over geographical areas of the state*: It is desired that as much as possible, the entire state should be covered by a reasonably even distribution of ATRs. There should be no "glaring" pockets of areas devoid of an ATR. This is especially valid in the case of Indiana, where the density of the road network is quite uniform over all areas of the state. In locating additional ATRs therefore, priority will be given to potential sites that are farthest from an existing ATR. The best location is one for which the nearest existing ATR is a maximum.

5. *Existing sites used for other count programs (possibility of upgrading)*: The *Traffic Monitoring Guide* states that the tie-in of new ATR locations to other count programs is vital. There are two possibilities for this: a) locating the new ATR close to an existing equipment used by another program, e.g., speed monitors, b) upgrading an existing equipment used by another count program, e.g., upgrading volume-counting Telemetry sites to carry out vehicle classification and weight measurements. The first possibility offers the opportunity to carry out studies using data collected by the different count equipment at a particular point or period in time. The second possibility offers tremendous possibilities in cost savings (by avoiding the setting-up of new sites) and maximum capacity utilization of equipment at existing stations. In cases where an existing site for another count program is a candidate for upgrading, the age and condition of the equipment should be evaluated before deciding on the upgrade. Obviously, equipment that consistently malfunction, and very old equipment have little chance of successful upgrading and should be excluded from the possible list of choices.

The experience of other states in distributing their ATR stations has been varied. For the Pennsylvania DOT, the emphasis for locating WIM was on the need to concentrate on the interstate system, and to relate to existing truck weight data collection efforts, so as to avoid duplication of resources. The state of Delaware chose its WIM locations based on their proximity to state borders so that sharing of costs and data with neighboring sates could be made possible. Also, this state distributed its additional ATR sites based on an effort to achieve a balanced geographical distribution, and to utilize existing HPMS sites and locations that were currently in use by other monitoring programs such as the LTPP (SHRP). For the State of Indiana, INDOT distributed the WIM sites based on factors that included pavement types, for the Long Term Pavement Program (LTPP).

(g).2.1 Description of method used for selection of ATR locations

1. *"Nomination" of potential sites*

Potential sites considered for the location of additional ATRs were taken from the following categories:

a) Existing continuous count sites presently used to collect other traffic data, e.g., speed monitoring sites and Telemetry sites
b) Suitable old sites at which a power source (for operating ATR equipment) may be readily available)
c) Sites based on engineering judgment.

2. *Allocation of points*

For each potential ATR under consideration, points were assigned to reflect how that site fares with regard to each factor. For example, if the potential location lies on an NHS segment, it is assigned a point of 1 for that factor. Otherwise, that potential site is given a value of 0.

This zero/one point allocation method was used for all factors with the exception of the "geographical distribution" factor. For this factor, a maximum point of 1 was given to the best location found by network analysis. This location was then assigned the status of an existing ATR, and network analysis is repeated to obtain the next best location. This procedure was repeated until all the potential ATRs are finished, and the final output is a ranking of potential sites from the geographical distribution perspective. The last site is given a point of zero, and all other potential sites are allotted points on a pro-rated basis, between 0 and 1.

3. *Application of weights to points, and ranking*

Desired values of weights attached to the various factors were used for the analysis. Each point assigned to a potential site for a particular factor was weighted by multiplying the value of the point by the weight for that factor, e.g., a potential ATR location that lies on an NHS segment has a point of 1 for that factor. Because the NHS factor has a weight of 15%, the weighted "NHS factor" points for that potential location is $1*15\% = 0.15$.

For each potential ATR location, the weighted points for all factors were summed up to give the total weighted points for that location. The locations were then ranked in ascending order of choice: The site with the highest total weights is the first choice for an additional ATR. For instance, if only 10 sites are needed, then the first 10 locations on the list of ranked locations are selected.

C-1: CONTINUOUS COUNTS FOR TRAFFIC VOLUMES

C-1.1 Introduction:

According to the *Traffic Monitoring Guide (TMG)*, p.3-1-1, the measurement of traffic volumes is one of the most basic functions of highway planning and management. The TMG presents an approach for restructuring continuous ATR programs in order to achieve the following objectives :

- development of adequate and reliable seasonal factors, based on a cost-efficient approach
- provide a statistical basis for analysis
- integrate the continuous program with the overall traffic monitoring program
- minimize modifications to the existing continuous program
- emphasize development of a consistent approach for national analysis
- establish minimum precision levels for seasonal factors.

Currently, continuous traffic volume counts are carried out in Indiana at 58 Telemetry and 34 WIM stations distributed geographically over the entire state. (See map in Appendix C-1(a)). A sample of volume data generated at these sites is attached as Appendix 15.

The objectives of this section of the study are:
(i) Determination of the most appropriate criterion for grouping volume-counting ATRs
(ii) Determination of the adequacy of the existing number of volume-measuring ATR stations and the distribution of any additional such stations.

i) **Determination of best grouping criterion and establishment of appropriate factors**

The best grouping criterion for grouping traffic volume ATRs has been determined, and this has been used to establish the appropriate factors for adjustment of short term counts, and also for determining whether any additional ATR sites are needed.

According to the *Traffic Monitoring Guide*, p. 3-2-6, assessment of the adequacy of ATR sites must be preceded by validation of the existing method of seasonal grouping. From the results of the precision and cluster analysis, the most appropriate criterion for grouping the ATR sites was selected, and the seasonal factors generated by the selected criterion are recommended for use by INDOT.

Cluster analysis performed on 1995 ATR traffic volume data, using MINITAB10 computer software yielded the natural groupings shown in Appendix C-1.4. The cluster analysis was first performed without specifying the number of clusters as an input parameter, and then by specifying a desired number of clusters ranging from 3 to 6.
The discussion below includes a description of each grouping criterion considered, an examination of how well the grouping criterion compares with the natural grouping offered by cluster analysis, and an evaluation of the precision of data values associated with the members of each group criterion. From the outcome of these discussions, an

overall assessment of each grouping criterion is made against other criteria, and the most appropriate criterion is selected. Thus, the selected criterion provides the most appropriate factors for adjustment of 48-hour counts into annualized statistics.

ii) **Assessment of adequacy of volume-counting ATR sites and distribution of any additional sites required**

From p. 3-2-6 of the TMG, having established the appropriate seasonal groups, the number of continuous ATR locations needed to achieve the desired precision level of the monthly factors for each seasonal group should be determined. The underlying premise of this exercise is that "more counters may be required for groups which have higher within-group variability." (p.55, *AASHTO Guidelines for Traffic Data Programs.*) The coefficient of variation is a measure of the variability of the monthly factors within each group. For a given significance level, a higher coefficient of variation requires a greater minimum number of ATR sites to achieve a specified precision.

ATR locations in INDOT's continuous count program are not randomly distributed, but it is assumed for the purpose of the analysis that these existing locations are equivalent to a simple random sample selection (a pseudo-random assumption). Once this assumption is made, normal distribution theory provides the appropriate methodology to obtain the minimum number of sites. (TMG p. 3-2-6 to p. 3-2-7).

The number of additional sites associated with the chosen criterion is selected as the extra number that needs to be installed by INDOT. Furthermore, the selected criterion provides a basis for adjustment of 48-hour counts into annualized statistics.

C-1.2 Results of the analysis and discussions

Criterion A: Grouping strictly based on the results of the cluster procedure where the number of clusters is not specified by the user.
Clustering monthly factors for volume data without initial specification of desired number of clusters produced the group list shown in Appendix C-1.4.

Table C-1.2A (a) Summary of Precision Analysis, Criterion A, Traffic Volumes, 1995

Group	Coefficient of Variation %	Precision %
1	0.8886	0.6356
2	0.2570	0.0959
3	6.7434	10.7287
4	0.2642	0.1045
5	5.5187	8.7803
6	4.4837	4.2838

The precision analysis shows that the coefficient of variation and precision for most of the groups are relatively low. This reflects the fact that clustering provides a natural means of grouping without regard to characteristics of the data sources, i.e., this grouping criterion is not encumbered by "forced association" of data units into groups.

A summary of the results of the adequacy analysis, provided in Table C-1.2A(b) below, shows the additional number of ATR sites needed for each group within this grouping criterion. The analysis carried out using this criterion indicated that very few additional traffic volume ATR sites are needed, i.e. a total of 3 are needed. This finding is consistent with expectation, because this criterion provides a very good natural grouping, and is therefore associated with very low variation of data units within any of its groups.

Table C-1.2A (b) Summary of Adequacy Analysis, Criterion A, Traffic Volumes, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional number of ATR sites needed
Group 1	2	10	-
Group 2	2	30	-
Group 3	5	4	1
Group 4	2	27	-
Group 5	4	4	-
Group 6	4	2	2

The only serious drawback of this otherwise excellent grouping criterion is that the number of clusters (and number of ATRs within each cluster) varies from year to year. Ritchie (1992) also made such an observation when he tried to use cluster analysis as a basis for grouping ATR sites in the state of Washington. This inconsistency violates a necessary requirement spelled out by the *AASHTO Guidelines for Traffic Data Programs* that the composition and number of groups should be consistent from year to year. Indeed, the importance of ensuring such consistency cannot be over-emphasized, otherwise each year would have its unique number of groups, group list, and additional number of sites needed. Hence this criterion cannot be adopted by itself for use by INDOT to group its traffic volume ATR stations.

However, the grouping offered by this criterion serves as yardstick against which other criteria are measured in determining how well the grouping offered by these criteria match a natural unrestrained grouping.

<u>Criterion B</u> (Grouping strictly based on results of cluster analysis where the number of clusters is specified)
The clustering analysis package available in MINITAB 10 makes it possible for the user to specify the number of clusters desired. Three, four, five and six clusters were specified as input parameters, in separate runs, to observe the variation patterns for each specification. It can also serve as a basis of comparison with other grouping criteria, based on road characteristics such as functional and area classes. The range of number of clusters, i.e., 3-6, was used because it is the range of the number of seasonal groups recommended by *Traffic Monitoring Guide* for most states.

B.1 Clustering with number of clusters specified as 3

Details of the results of the cluster procedure in which the number of desired clusters was specified as 3, are provided in Appendix C-1.4.B1, while Appendix C-1.2.B1 shows month-by-month details of the precision analysis for this grouping criterion. Table C-1.B1(a) below shows a summary of the results of the precision analysis.

Table C-1.2B1(a) Summary of Precision Analysis, Criterion B1, Traffic Volumes, 1995

Group	Coefficient of Variation %	Precision %
1	0.2298	0.0769
2	0.2570	0.0960
3	2.8346	2.2076

Results of precision analysis carried out for groups formed on the basis of this criterion are shown in Table C-1.2B1 above. This analysis indicates relatively low values of coefficient of variation and corresponding precisions.

Table C-1.2B1(b)Summary of Adequacy Analysis, Criterion B1, Traffic Volumes, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	2	37	-
Group 2	2	30	-
Group 3	2	10	-

Like Criterion A, the disadvantage of this criterion is that the number of clusters are not consistent from year to year.

B.2 Clustering with number of clusters specified as 4

The cluster procedure carried out with the specified number of clusters desired as 4 yielded results not very different from that of the 3-clusters. Generally, very low coefficients of variation were obtained, and coupled with the low t-statistics for the large number of sites in each of these groups, this translates into very good values of precision. The only group whose precision was poor enough to fall just outside the threshold was Group 4, but the adequacy analysis shows that only 1 additional ATR site is needed to bring the ATR data in this group to the required range of statistical precision. The details of the clustering results, precision analysis, and adequacy analysis are provided as Appendices C-1.4.B2, C-1.2.B2, and C-1.3B2, respectively. In Tables C-1.B2(a) and C-1.B2(b), summaries of the precision and adequacy analysis respectively, are provided.

Table C-1.2B2(a) Summary of Precision Analysis, Criterion B2, Traffic Volumes, 1995

Group	Coefficient of Variation	Precision
1	0.2298	0.0769
2	0.2570	0.0959
3	3.3912	3.5594
4	6.7434	10.7286

Table C-1.2B2(b) Summary of Adequacy Analysis, Criterion B2, Traffic Volumes, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	2	37	-
Group 2	2	30	-
Group 3	3	6	-
Group 4	5	4	1

Like Criterion A, the disadvantage of this criterion is that the number of clusters are not consistent from year to year.

B.3 Clustering with number of clusters specified as 5

For 5 desired clusters specified, the cluster procedure generates a similar grouping pattern as that for the 4-cluster criterion. The main difference is that Group 1 for the 4-cluster group list is now broken into 2 groups, whereas all other groups remain the same in size and composition. Very low coefficients of variation, reflective of the efficacy of the clustering process, result in very good precision values. With the exception of Group 4 (where only 1 additional ATR site is needed) all groups have excess sites.

Table C-1.2B3(a) Summary of Precision Analysis, Criterion B3, Traffic Volumes, 1995

Group	Coefficient of Variation %	Precision %
1	0.8886	0.6356
2	0.2642	0.1045
3	0.2570	0.0959
4	3.3912	3.5594
5	6.7434	10.7287

Table C-1.2B3(b) Summary of Adequacy Analysis, Criterion B3, Traffic Volumes, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	2	10	-
Group 2	2	27	-
Group 3	2	30	-
Group 4	3	6	-
Group 5	5	4	1

B.4 Clustering with number of clusters specified as 6
The results for this specification were the same as that obtained by not specifying the number of clusters (see B.1).

<u>Criterion C</u> (Grouping based on "old" INDOT group list)
The "old" INDOT group list is the current list being used by INDOT for grouping of ATR sites for annualization of 48-hour counts, application of growth factors and other analyses that involve grouping. This group list is as follows:

Group 1: Urban Interstates, Freeways and Expressways
Group 2: Urban Principal Arterials, Minor Arterials, Collectors, and Locals
Group 3: Rural Interstates
Group 4: Rural Principal Arterials and Minor Arterials
Group 5: Rural Collectors and Locals

INDOT's selection of these seasonal groups were not based on any statistical method or analysis, but through engineering judgment and using the general list of groups recommended by the FWHA in the *Traffic Monitoring* Guide.

This criterion offers 5 seasonal groups, which is considered satisfactory. The TMG states that, in general, 3-6 seasonal groups are usually sufficient to address traffic patterns in a state.

The nature of INDOT's current group list is in accordance with recommendations in the *Traffic Monitoring Guide*, p. 3-2-4 , where it is argued that the establishment of seasonal patterns should be based on functional classes or a combination of functional classes, and not solely on the previously-used basis of random variation, which groups locations that show similar patterns of variation.

The TMG states that the definition of seasonal patterns based on functional class is essential, not only for the application of the statistical process to determine the appropriate number of ATR sites, but also for the provision of a consistent national framework for comparison between States. And most importantly, it provides a simple procedure for allocating coverage counts to the factor groups for estimation of annual average daily traffic (AADT).

The individual elements found in INDOT's list include the elements recommended, as a minimum, in any state's ATR grouping, by the TMG on p.3-2-6. The only exception is the 'Recreational' group, which is recommended by the TMG, but is not included in INDOT's list. According to the TMG (p. 3-2-5), "Typical monthly variation patterns for urban areas have a coefficient of variation under 10%, while those of rural areas range between 10 to 25%. Values higher than 25% are indicative of highly variable travel patterns which this Guide terms 'recreational' patterns but may be due to other reasons [aside from recreational travel]". Examination of previous monthly variation patterns for

the State of Indiana reveal that the coefficients of variation do not exceed 25%, hence INDOT's exclusion of the recreational group from its seasonal group list is justified.

As can be seen from Appendix C-1, the cluster analysis results provide a fairly strong corroboration of the existing grouping currently used by INDOT. However, due to the "forced" association of the data units (ATR monthly factors) into pre-determined classes (functional classes), it is not surprising to find fairly high coefficients of variation for some of the groups (see Table C-1.2.C below) from the results of precision analysis.

Table C-1.2C(a2) Summary of Precision Analysis, Criterion C, Traffic Volumes, 1995

Group	Coefficient of Variation %	Precision %
Urban Interstates, Freeways & Expressways	7.5320	4.3481
Urban Principal Arterials, Minor Arterials, Collectors, and Locals	16.3900	8.4273
Rural Interstates	7.8540	5.6180
Rural Principal Arterials and Minor Arterials	10.6256	4.8251
Rural Collectors and Locals	0.7530	0.4143

Adequacy analysis for 1994 data using this grouping criterion indicated that quite a few additional sites are needed. However, that year's data set does not include the truck weighing ATRs (WIMs) which also measure traffic volumes. Thus any recommendations based solely on that year's data set would be erroneous. The 1995 data set provided by INDOT was more complete as it included data from WIM sites. A summary of the adequacy analysis for this criterion using 1995 data is shown in Table C-1.C(b2), while details of this analysis are provided in Appendix C-1.3.C.

Table C-1.2C(b1) Summary of Adequacy Analysis, Criterion C, Traffic Volumes, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional number of ATR sites needed
Group 1	5	14	-
Group 2	13	17	-
Group 3	5	10	-
Group 4	7	21	-
Group 5	2	15	

Criterion D (Grouping based on FHWA's HPMS classes)

FHWA's HPMS classes are the classes provided in Appendix G of the *HPMS Field Manual*, for reporting of data for the nationwide Highway Performance Monitoring System (HPMS).

Table C-1.2D(a) Summary of Precision Analysis, Criterion D, Traffic Volumes, 1995

Group	Coefficient of Variation %	Precision %
Rural Interstates	7.8470	5.6130
Urban Interstates	10.0100	5.7786
Urban Freeways and Expressways	10.5800	9.7852
Rural Principal Arterials	8.7250	4.8322
Rural Minor Arterials	5.1960	3.7167
Rural Collectors and Locals	12.2600	30.4580
Urban Principal Arterials	11.4800	7.7119
Urban Minor Arterials	11.5500	18.3760
Urban Collectors and Locals	9.9900	89.7550

The group list offered by this criterion appears to be ideal because it provides a view of the variation of data patterns across a relatively broad spectrum of road functional classes. Furthermore, it provides seasonal adjustment factors for annualization of short-term counts for each of these groups. However, it can be seen from the precision analysis that such a criterion is associated with very high values of variation and poor precision values.

Table C-1.2D(b) Summary of Adequacy Analysis, Criterion D, Traffic Volumes, 1995

Group	Required nr. of ATR sites	Existing nr. of ATR sites	Additional nr. of ATR sites needed
Rural Interstates	5	17	-
Urban Interstates	7	16	-
Urban Freeways and Expressways	7	9	-
Rural Principal Arterials	6	15	-
Rural Minor Arterials	4	12	-
Rural Collectors and Locals	9	3	6
Urban Principal Arterials	8	12	-
Urban Minor Arterials	7	4	3
Urban Collectors and Locals	6	2	4

Adequacy analysis carried out using this data set indicated relatively large numbers of additional sites required. This is attributed to the few numbers of ATR sites in most of the groups. The existing number of sites is thinly stretched among the several number of groups associated with this criterion. Any recommendation based on the adequacy analysis using this criterion would clearly be relatively expensive.

Criterion F (Grouping based on a combination of area and functional classes)
Some states, such as Kansas, have found out that traffic patterns on their roads are adequately captured using a combination of area and functional classes as follows:

Group 1: Rural Interstates and Other Principal Arterials
Group 2: Rural Other, i.e., Minor Arterials, Major and Minor Collectors, Locals.

Group 3: Urban Interstates, Other Principal Arterials, and Freeways and Expressways.
Group 4: Urban Other, i.e., Minor Arterials, Major and Minor Collectors, Locals.

The group list offered by this criterion is rather simple. Like grouping Criterion C, this criterion provides seasonal adjustment factors for annualization of short-term counts for each of these groups. However, unlike Criterion D, it does not provide a view of the variation of data patterns across a relatively broad spectrum of road functional classes. The advantage this criterion has over Criterion D is that all the groups currently have adequate numbers of ATR sites. Table C-1.F(a) shows the summary of results for the precision analysis, while the summary of the adequacy analysis for this criterion is given in Table C-1.F(b)

Table C-1.2F(a) Summary of Precision Analysis, Criterion F, Traffic Volumes, 1995

Group	Coefficient of Variation %	Precision %
1	9.4546	3.9930
2	9.8859	4.3839
3	10.0430	4.1457
4	11.0270	11.5740

Table C-1.2F(b) Summary of Adequacy Analysis, Criterion F, Traffic Volumes, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional number of ATR sites needed
Group 1	6	24	-
Group 2	7	22	-
Group 3	7	25	-
Group 4	8	6	2

Criterion G (Grouping based on functional classes only)
This grouping criterion was used to determine whether traffic volume patterns are not significantly influenced by area, regional, and peripheral classes. The following grouping list was used for the analysis:

Group 1: Interstates
Group 2: Other Freeways & Expressways, and Other Principal Arterials
Group 3: Minor Arterials
Group 4: Collectors and Locals

It is observed from Table C-1.2G(a) that the coefficients of variation for each group is fairly low, ranging approximately between 8 and 11%. The number of ATR stations within each group varies from 10 to 25. This reveals that the ATR sites in the states are well distributed among the functional classes. However, in reality, this is not the yardstick

for measuring appropriateness of distribution of sites. The proper yardstick is the precision inherent with data from the ATRs within each group. Table C-1.2G(a), which presents a summary of the precision analysis, shows that all the groups have precision values which are well within the 10% threshold. Therefore, no additional ATR traffic volume sites are needed, from the perspective of this grouping criterion. This is seen in Table C-1.2G(b).

Table C-1.2G(a) Summary of Precision Analysis, Criterion G, Traffic Volumes, 1995

Group	Coefficient of Variation %	Precision %
1	8.0444	3.3974
2	11.1730	4.6122
3	11.1410	7.9692
4	9.4263	4.8468

Table C-1.2G(b) Summary of Adequacy Analysis, Criterion G, Traffic Volumes, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional number of ATR sites needed
Group 1	5	24	-
Group 2	8	25	-
Group 3	8	10	-
Group 4	6	17	-

Criterion H (Grouping based on regional and functional classes)

The *AASHTO Guidelines for Traffic Data Programs* suggests that some states may be able to detect regional patterns in their traffic data. This grouping criterion is characterized by ATRs grouped on the basis of their regional locations (north versus south), and their functional classes, i.e., high class roads versus lower road classes. A list of the groups for this criterion is shown below:

Group 1: Northern Interstates
Group 2: Northern Other
Group 3: Southern Interstates
Group 4: Southern Other

Table C-1.2H(a) shows a summary of the precision analysis for this grouping criterion.

Table C-1.2H(a) Summary of Precision Analysis, Criterion H, Traffic Volumes, 1995

Group	Coefficient of Variation %	Precision %
1	8.5360	5.1587
2	6.4620	4.6223
3	8.0870	3.2671
4	13.1400	5.1992

It can be seen from the precision analysis that the coefficients of variation within groups are fairly low, with the exception of Group 4, which has a coefficient of variation of 13.14%. However, the large number of ATRs in this group offsets the effect of the high variation coefficient, because the existing precision is about 5% which is good. From the adequacy analysis, it is seen that no additional ATR sites are needed for the grouping criterion.

Table C-1.2H(b) Summary of Adequacy Analysis, Criterion H, Traffic Volumes, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional number of ATR sites needed
Group 1	6	13	-
Group 2	5	10	-
Group 3	6	26	-
Group 4	10	27	-

Criterion I (Grouping based on peripheral and functional classes)
The possibility that traffic volume patterns at or near the state borders differs from patterns in the inner parts of the state, was examined as part of this study. For this investigation, the following group list was formulated and analyzed:

Group 1: Peripheral Interstates
Group 2: Non-peripheral Interstates
Group 3: Peripheral Other
Group 4: Non-peripheral Other

The results obtained for this grouping criterion were rather interesting. Variation of data units within groups were quite low, ranging from 7.5% to 10.6% (Table C-1.2I(a)). Excellent values of precision were obtained, with a maximum of 5.4%. The average precision for this criterion is better than that of any other considered in the study, with the exception of Criterion C and those criteria based strictly on the results of cluster analysis. The minimum number of ATRs required for each group ranges from 5 to 7, as seen in Table C-1.2I(b).

Table C-1.2I(a) Summary of Precision Analysis, Criterion I, Traffic Volumes, 1995

Group	Coefficient of Variation %	Precision %
1	7.5549	5.4040
2	8.2411	4.9805
3	10.1160	4.3748
4	10.6940	4.0610

Table C-1.2I(b) Summary of Adequacy Analysis, Criterion I, Traffic Volumes, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional number of ATR sites needed
Group 1	5	10	-
Group 2	6	13	-
Group 3	7	23	-
Group 4	7	29	-

Criterion J (Grouping based only on regional locations)
The state of Indiana has a somewhat regular geometric shape, with various sections of the state experiencing different rates of growth. The central parts of the state that serves as a conduit for state crossing traffic and is also the economic and administrative center of the state. It is probable that the traffic patterns across the state may not be adequately captured by a mere rural/urban classification, and that it may be possible to detect distinct patterns within regional areas grouped as shown below:

Group 1: Northwestern
Group 2: Northeastern
Group 3: Southwestern
Group 4: Southeastern
Group 5: Central

A list showing the location of ATRs with respect to these regional groupings are provided in Appendix C-4.3.

Table C-1.2J(a) Summary of Precision Analysis, Criterion J, Traffic Volumes, 1995

Group	Coefficient of Variation %	Precision %
1	8.7022	4.4744
2	6.2011	3.5798
3	12.9980	5.6211
4	9.8004	6.2269
5	8.2894	5.9294

The precision analysis shows fairly low values of variation coefficients between groups. Also, the precision values are fairly good, and no additional traffic volume ATR sites are needed for this criterion. This can be seen in Tables C-1.2J(a) and C-1.2J(b), which provide summaries of the precision and adequacy analysis, respectively.

Table C-1.2J(b) Summary of Adequacy Analysis, Criterion J, Traffic Volumes, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional number of ATR sites needed
Group 1	6	17	-
Group 2	4	14	-
Group 3	9	23	-
Group 4	7	12	-
Group 5	6	10	-

C-1.3 Summary of results and discussion

The table below shows the overall summary of the results of precision analysis for all criteria:

Table C-1.3a Summary of precision analysis

Criterion	Average Coefficient of Variation (%)	Average Precision (%)
A (Strictly cluster)	1.0616	2.2131
B1 (Strictly cluster)	0.5787	0.3375
B2 (Strictly cluster)	0.8248	0.9090
B3 (Strictly cluster)	0.9223	0.9913
B4 (Strictly cluster)	1.0616	2.4205
C (Current INDOT grouping)	**9.0456**	**3.7772**
D (FHWA grouping)	9.1525	9.6656
F (Area/functional classes)	9.8897	5.7444
G (Functional classes only)	9.6628	4.6613
H (regional/functional classes)	9.6186	4.3973
I (peripheral /functional classes)	9.4218	4.0709
J (regional classes only)	9.5350	5.0805

Discussion of results of the cluster analysis

The clustering procedure yielded 6 clusters when the number of clusters desired was not specified in the MINITAB program. This was found to be similar to the results when 5 clusters were specified, with the exception that 2 ATRs i.e., Laporte 4250 and Monroe 2930, for the 6-clusters, fell out to form a group of their own. There is clearly no definable pattern between these two ATR stations as they are of different area class, and different regional and peripheral attributes. Therefore, the 5 cluster results may be considered as one that best provides an insight into traffic volume ATR data in the state.

Appendix C-1.4 provides a preliminary interpretation of the results of the cluster analysis for traffic volumes. From the first row in this table, it is clear that ATRs on Rural Interstates form a very strong majority in the cluster group on that row. Also, ATRs on Other Arterials and non-peripheral counties indicate a fair degree of dominance in that group, whereas ATRs in the southwestern region have only a weak dominance. The next cluster group (2^{nd} row on this table) shows Urban areas as having a fair majority. Also, Other Arterials and Minor Arterials constitute a fair majority. However, closer examination of the attributes in this group shows that most of the “Other Arterials” belong to the rural class. It would therefore be erroneous to describe this group as predominantly “Urban Other Arterials”.

The next dominant functional class is Interstates. This somewhat suggests that Urban Interstates may appropriately represent the majority (albeit weak majority) functional class attribute of ATRs in this group. Also, peripheral ATRs indicate weak dominance in this group, and the “dominance” of this group may be discounted.

The next cluster group, which has 30 observations, is characterized by ATRs of very divergent attributes. However, from close scrutiny a fair degree of dominance is observed to be exhibited by Rural ATRs, while Interstates and non-peripheral ATRs constitute weak majorities. Non-peripheral rural interstates may be an apt description, tentatively, for this group.

For the fourth cluster group, Rural ATRs form a convincing majority, while Other Arterials dominate the functional class attributes.. The next dominant functional class attribute in this group is “Collectors”. Southwestern ATRs form quite a strong majority, while there is a tie between peripheral and non-peripheral ATRs. The 5^{th} cluster group shows a tie between the rural and urban classes, while Other Arterials form a strong majority. ATRs in the northwest region have a fair degree of dominance in this group, while non-peripheral ATR dominate this group completely.

Generally, it is observed that the effect of peripheral and regional classes in all cluster groups for traffic volume ATRs are minimal, and if these two attributes are ignored, the 5 cluster groups are found to bear a somewhat close resemblance to the current groups used by INDOT for grouping traffic volume ATR data. This is shown in the table below:

Table C-1.3b Comparison of groupings of cluster analysis and that of Criterion C

Group	Cluster groupings	Criterion C (Current INDOT Seasonal Factor groupings) for Traffic Volume ATRs
1	Cluster group 1 Rural (strong dominance) OPA, MA (fair dominance)	INDOT Group 4: Rural OPA and MA
2	Cluster group 2 Urban (fair dominance) Interstate (close second dominance, next to OPA and MA)	INDOT Group 4: Rural OPA and MA
3	Cluster group 3 Rural (fair dominance) Interstate (fair dominance)	INDOT Group 4: Rural OPA and MA
4	Cluster group 4 Rural (strong dominance) Collector (close second dominance, next to OPA and MA)	INDOT Group 4: Rural OPA and MA
5	Cluster group 1 Rural (strong dominance) OPA, MA (fair dominance)	INDOT Group 4: Rural OPA and MA

Among the non-cluster criteria, C provides the best seasonal group list for traffic volumes, for the following reasons:

1. It has the lowest average and total variation of data units within its groups than any other non-cluster grouping criterion, as seen in the table above.
2. It has the best average precision values for data units in each group, compared to all other non-cluster grouping criteria.
3. Unlike the 5 cluster grouping criteria (A to B4), Criterion C (as well as criteria D to J) provides a list of seasonal groups to which any short term count can be assigned as a basis for annualization of such short-term counts.
4. The number of groups in this criterion and the composition of its groups show the closest resemblance to those of the cluster analysis.

Selection of the best criterion is accompanied by establishment of appropriate factors that may be used for adjustment of short term counts, and determination of the minimum number of traffic volume ATR sites needed. The current INDOT factors are therefore appropriate and may continue to be used for such purposes.

The adequacy analysis for this group criterion revealed that no additional traffic volume ATR sites are needed. Rather, all the groups have an excess number of sites, and a specified number of these sites, for each group, may be deleted or may be rendered non-operational without affecting the statistical validity of data generated at the sites.

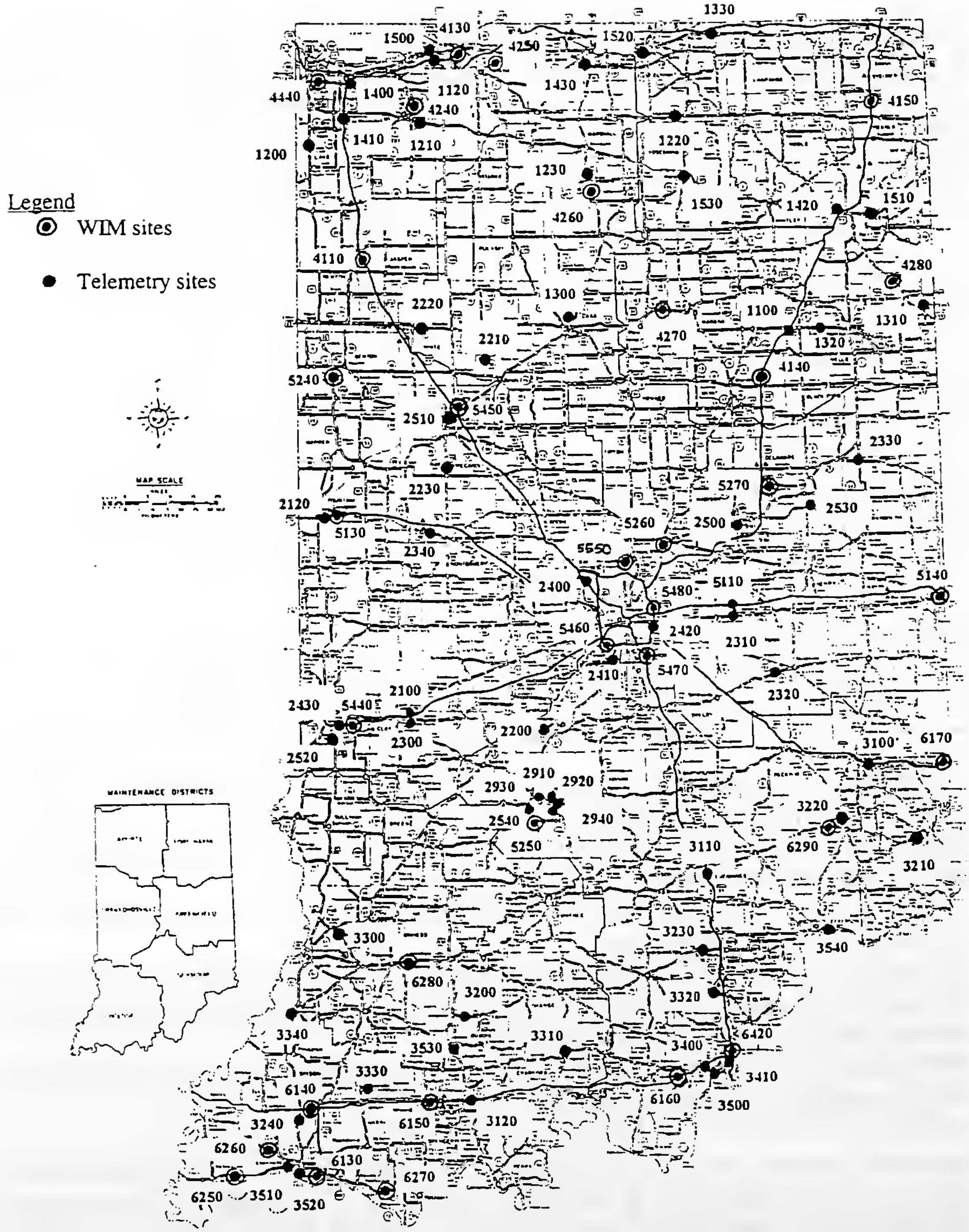


Figure C-1(a)
Map of the State of Indiana showing locations of existing traffic volume ATRs

C-2: CONTINUOUS VEHICLE CLASSIFICATION COUNTS

C-2.1 Introduction

Vehicle classification is the observation of highway vehicles and the subsequent sorting of the resulting data into a fixed set of categories depending on the size, axle configuration, and type of vehicle.

Vehicle classification data are of immense use to agencies involved in almost every aspect of transportation planning, engineering, and finance. Examples of activities that make use of vehicle classification data include:

- pavement analysis and design, and pavement management
- scheduling resurfacing, reconditioning, and reconstructing of highways based on projected residual pavement life
- predicting commodity flows and freight movements
- providing design input relative to current and predicted capacity of highways
- developing weight enforcement strategies
- accident record analyses
- environmental impact analyses, including air quality studies, and
- analysis of alternative highway regulatory and investment policies

The *Traffic Monitoring Guide* states that vehicle classification data are extremely important as transportation agencies and State legislatures grapple with the need to determine and allocate the costs associated with maintaining the highway system and in selecting the improvements that will be programmed.

The existing situation

Currently in the State of Indiana, continuous vehicle classification counts are carried out using the weigh-in-motion (WIM) equipment located at 34 stations on the state network. (See map in Appendix C-4.2). At each station, the characteristics recorded for each vehicle allow for a variety of vehicle classification analyses, such as sorting out the data into the 13 FHWA classifications.

A sample of vehicle classes by day-of-month report for a typical station is attached as Appendix C-2.5. A description of FHWA vehicle classifications and typical vehicle silhouettes are attached as Appendices C-2 (f) and (g) respectively.

Need for the study

An assessment of the continuous vehicle classification counts program is necessary for the following reasons:

(i) Determination of the most appropriate criterion for grouping classification ATRs

(ii) Establishment of appropriate factors to provide an indication of spatial and temporal trends in commercial vehicle movements

(iii) Determination of the adequacy of the existing number of vehicle-classification ATR stations and distribution of any additional number of such stations

i) **Determination of best grouping criterion:**

The best criterion for grouping vehicle-classification ATRs has been determined, and this has been used to establish the appropriate factors for the possible adjustment of short term counts, and also for determining whether any additional vehicle-classification ATR sites are needed.

ii) **Establishment of appropriate factors:**

According to the *Traffic Monitoring Guide*, vehicle classification volumes are subject to wide variability due to seasonal patterns, day-of-week, etc. Trucks and other commercial vehicles serve different purposes and may have travel patterns that differ from those of automobiles. The collection of short monitoring periods using the sample design specified in this section allows the development of unbiased system estimates of commercial vehicle percentages, which, when multiplied by total VDT, result in classified VDT estimates.

However, a short monitoring period at a site represents only the classified volumes during the specific period of monitoring at that site (assuming no equipment error).
In order to provide annual average estimates of percentages of vehicles, the *Traffic Monitoring Guide,* on page ..... states that it is "necessary to develop and apply factors, as was done in Section 3 to estimate AADT."

On page 57 of the *AASHTO Guidelines for Traffic Data Programs*, it is stated that permanent vehicle classification devices are used to calculate monthly vehicle classification ratios in the same manner as described for volume. However, the *AASHTO Guidelines* caution that the grouping of data collection sites for seasonal variation of vehicle classification is not necessarily the same as that for traffic volume.

- *The Traffic Monitoring Guide*, on p. 4-1-2, recognizes that, in an attempt to establish appropriate factors to determine vehicle classification patterns, the following issues may have to be addressed :

- *Adequacy of data base*: To develop these temporal and spatial factors, it is necessary to have an established and geographically distributed base of continuous classifiers. Many States have continuous volume counters and some of these are capable of classifying by length, but the collection and processing of these data have not been a high priority. These continuous classification counters, if available, provide the starting point for the exploration of classification variability. In addition, as a result of the SHRP program, many states have obtained permanent classifiers capable of classifying in the 13 standard FHWA categories. Therefore, data bases needed to pursue classification factors may be available.

- *Development of factors*: Research is necessary to develop an appropriate process for the development of factors. In terms of AADT, the process is based on day-of-week,

monthly variation, and established seasonal group patterns. This is the recommended approach for vehicle classification at this time. However, due to the different purposes of truck travel, alternative processes have to be explored. In addition, the development of appropriate spatial patterns for classification categories will be difficult. According to the TMG, research on this issue is in progress, and it remains to be seen if alternative processes are more effective.

- *Appropriate factor(s) to be chosen to reflect vehicle classification patterns*: It is unclear whether factors are needed for each classification category or whether a global approach applies to all truck traffic. For example, due to different travel purposes and uses in industry, single-unit trailer-combination trucks may have different travel patterns than twin-trailer combination trucks. The temporal and spatial variability of different classes of vehicles will have to be analyzed before an answer can be provided.

- *Capability of equipment*: The capability of vehicle classification equipment will need detailed analysis. Volume counters are, in general, highly accurate. To achieve acceptable levels of accuracy for vehicle classification data collection, agencies should assess the appropriateness of the algorithm used in the classification process. The algorithm should be specific to the traffic composition in each State. Some States have opted to retain individual vehicle information (number of axles and distance between axles) rather than only recording the FHWA vehicle type. Individual vehicle records are then sorted into the appropriate FHWA classes while retaining the ability to do more detailed analysis of the data, if needed. Whether using vehicle specific or aggregated data, the magnitude of classification error must be quantified for incorporation into the classification adjustment process.

- *Vehicle classification in urban areas*: The great difficulties in obtaining accurate vehicle classification counts in high-volume roads may create a data gap in urban areas. It is hoped that future technological developments will help to narrow this gap. At present, promising technology include magnetic imaging and video detection systems.

ii) **Determination of adequacy of vehicle classification ATR sites and distribution of additional sites required**

This study seeks to assess the adequacy of current vehicle-classification ATR sites, to provide an estimation of the additional number needed and the distribution of such additional sites. The study uses statistical tools and methods in order to achieve this objective. For vehicle classification data, INDOT has indicated preference for relatively high precision values, i.e., “99-10”. This means that out of every 100 classification measurements such as percent commercial vehicles, 99% should be expected to fall within 10% of the true value.

The steps used for the analysis are shown in the flow chart provided on page C.5.

C-2.2 Results of analysis and discussion

Using MINITAB10 software package, cluster analysis was carried out on data collected by vehicle-classifying automatic traffic recorders in the year 1995. As a first step, the cluster analysis was performed without specifying the desired number of clusters as an input parameter. Then the analysis was continued by specifying the desired number of clusters as 3, 4, 5, and 6.

In this section, the results of the cluster procedure for each specification are discussed. Also, the results of precision and adequacy analyses for the clustering-based criteria and the other formulated or existing grouping criteria are discussed. The discussions include a description of each grouping criterion considered, an examination of how well the grouping criterion compares with the natural grouping offered by cluster analysis, and an evaluation of the precision and adequacy of sites associated with the members of each group criterion.

From these discussions, each grouping criterion is evaluated against other criteria, and the most appropriate criterion for grouping vehicle-classifying ATRs is selected. Also, the number of additional sites associated with the chosen criterion has been determined. Furthermore, the selected criterion provides a basis for adjustment of 48-hour vehicle classification counts into annualized statistics.

Criterion A: Grouping strictly based on the results of the cluster procedure where the desired number of clusters is not specified as an input parameter.
Clustering monthly factors for vehicle classification data without initial specification of desired number of clusters produced the group list shown in Appendix C-2.2A.

Table C-2.2A(a) Summary of Precision Analysis, Criterion A, Vehicle Classification, 1995

Group	Coefficient of Variation %	Precision %
1	0.7769	1.0885
2	5.6702	6.3411
3	5.4071	6.6890
4	1.1848	1.9502

Table C-2.2A(b) Summary of Adequacy Analysis, Criterion A, Vehicle Classification, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	4	7	3 excess
Group 2	8	9	1 excess
Group 3	8	8	10
	4	4	2 excess

The precision analysis shows that the coefficient of variation and precision for the groups in this criterion are relatively low. This observation is a reflection of the capability of the cluster procedure to provide a natural means of grouping without regard to the characteristics of the data sources, thus providing relatively excellent precision values and low variation coefficients. Expectedly, this criterion is associated with a relatively large number of excess sites.

The main (and probably only) disadvantage of this and other strictly cluster-based grouping criteria is that the number of clusters (and number of ATRs within each cluster) varies from year to year. This conflicts with the recommendations put forth in the *AASHTO Guidelines for Traffic Data Programs* that the composition and number of groups should be consistent from year to year. This failing precludes the assignment of short-term classification counts to ATRs, and consequently cannot be used as basis for adjusting such counts.

This grouping criterion is useful for the rest of the analysis, however, because it serves as a yardstick against which other criteria can be measured. Using this, it can be determined how well the grouping offered by these criteria match this criterion (which is a natural and unrestrained grouping procedure).

Criteria B (Grouping strictly based on results of cluster analysis, where the number of clusters is specified)

Using MINITAB 10, it is possible for the user to specify the number of clusters desired. Three, four, five and six clusters were specified as input parameters, in separate runs, to observe the variation patterns for each specification and to serve as a basis for comparison between other grouping criteria considered in this study. The range used corresponds to the range of the number of seasonal groups recommended by *Traffic Monitoring Guide* (1994) for most states.

B.1 Clustering with number of clusters specified as 3

For 3 specifies clusters, details of the results of the cluster procedure are provided in Appendix C-2.B1, while Appendix C-2.B1 shows month-by-month details of the precision analysis for this grouping criterion. Table C-2.2B1(a) below shows a summary of the results of the precision analysis.

Table C-2.2B1(a) Summary of Precision Analysis, Criterion B1, Vehicle Classification, 1995

Group	Coefficient of Variation %	Precision %
1	6.5925	5.5858
2	0.25705.6702	6.3411
3	2.83465.4071	6.6890

Table C-2.2B1(b)Summary of Adequacy Analysis, Criterion B1, Vehicle Classification, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	9	13	4 excess sites
Group 2	8	9	1 excess site
Group 3	8	8	

Two of the 3 groups formed by this cluster specification are associated with excess sites, and thus no additional ATRs are required if this criterion is adopted. However, like all cluster criteria, the groups offered by this criterion are not consistent and do not permit does not yield annualization of short-term coverage counts.

B.2 Clustering with number of clusters specified as 4
The results for this specification were the same as that for criterion A.

B.3 Clustering with number of clusters specified as 5
The cluster procedure carried out with the specified number of clusters desired as 5 yielded results similar to the results for the previous criterion. The details of the clustering results, precision analysis, and adequacy analysis are provided as Appendices C-2.2B2(a) and C-2.2B2(b), respectively. In Tables C-2.2B2(a) and C-2.2B2(b), summaries of the precision and adequacy analysis, respectively, are provided.

Table C-2.2B2(a) Summary of Precision Analysis, Criterion B2, Vehicle Classification, 1995

Group	Coefficient of Variation	Precision
1	0.7769	1.0885
2	5.6702	6.3412
3	1.9869	2.7839
4	n.a.	n.a.
5	1.1847	1.9801

Table C-2.2B2(b) Summary of Adequacy Analysis, Criterion B2, Vehicle Classification , 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	4	7	3 excess
Group 2	8	9	1 excess
Group 3	5	7	2 excess
Group 4	n.a.	1	n.a.
Group 5	3	6	2 excess

The results showed low values of variation and good precisions. The worst precision value was 6.34%, which is well within the desired range of 0-10%. Quite expectedly, no additional ATR sites are needed from the standpoint of this grouping criterion. However, like Criterion A, the disadvantage of this criterion is that the number of clusters are not consistent from year to year.

B.4 Clustering with number of clusters specified as 6
For a desired cluster specification of 6, the cluster procedure generates a grouping pattern similar to that for the 5-cluster criterion. The main difference is that one of the groups in the 5-cluster grouping is now broken into 2 groups, whereas all other groups remain the same in size and composition. A summary of the precision and adequacy analysis are shown below.

Table C-2.2B3(a) Summary of Precision Analysis, Criterion B3, Vehicle Classification , 1995

Group	Coefficient of Variation %	Precision %
1	0.7769	1.0885
2	5.6702	6.3412
3	1.6794	4.9047
4	n.a.	n.a.
5	1.1847	1.9501
6	2.2166	2.7016

Table C-2.2B3(b) Summary of Adequacy Analysis, Criterion B3, Vehicle Classification, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	4	7	3 excess
Group 2	8	9	1 excess
Group 3	4	4	0
Group 4	n.a.	1	n.a.
Group 5	5	6	1 excess
	4	3	1 excess

The results obtained are similar to those of the previous criteria that have been considered.

Criterion C (Grouping based on current INDOT group list)
The current INDOT group list is the current list being used by INDOT for grouping of traffic volume ATR sites for annualization of 48-hour traffic volume counts, application of growth factors and other analyses that involve grouping. This group list is as follows:

Group 1: Urban Interstates, Freeways and Expressways
Group 2: Urban Principal Arterials, Minor Arterials, Collectors, and Locals
Group 3: Rural Interstates
Group 4: Rural Principal Arterials and Minor Arterials
Group 5: Rural Collectors and Locals

INDOT's selection of these seasonal groups were not based on any statistical method or analysis, but through engineering judgment and using the general list of groups

recommended by the FWHA in the *Traffic Monitoring Guide.* Even though this criterion was formulated for INDOT purposely for traffic volume ATRs, this study seeks to determine how well such a criterion may be applicable to vehicle classification ATRs.

Precision and adequacy analysis carried out on vehicle classification ATR data yielded high coefficients of variation and rather precision values, as is seen in Tables C-2.2C(a) and C-2.2C(b).

Table C-2.2C(a) Summary of Precision Analysis, Criterion C, Vehicle Classification , 1994

Group	Coefficient of Variation %	Precision %
1	7.6318	10.6941
2	n.a.	n.a.
3	17.4322	21.5651
4	21.3158	19.1123
5	19.1889	863.7361

Precision analysis showed that all groups in this criterion do not meet the precision requirement. Consequently, adequacy analysis for 1995 data using this grouping criterion indicated that a large number of additional ATR sites are needed. A summary of the adequacy analysis for this criterion using 1995 data is shown in Table C-2.2C(b) while details of this analysis are provided in Appendix C-2.3.C.

Table C-2.2C(b) Summary of Adequacy Analysis, Criterion C, Vehicle Classification, 1994

Group	Required number of ATR sites	Existing number of ATR sites	Additional number of ATR sites needed
Group 1	11	7	4
Group 2	n.a.	1	2
Group 3	32	12	20
Group 4	40	12	28
Group 5	39	2	37

Criterion D (Grouping based on FHWA's HPMS classes)
FHWA's HPMS classes are the classes provided in Appendix G of the HPMS Field Manual for reporting of data for the nationwide Highway Performance Monitoring System (HPMS). This study investigates the implications of adopting such a criterion for grouping vehicle classifying ATRs.
A description of this criterion group list is as follows:

Group 1: Rural Interstates
Group 2: Urban Interstates

Group 3: Urban Freeways and Expressways
Group 4: Rural Principal Arterials
Group 5: Rural Minor Arterials
Group 6: Rural Collectors and Locals
Group 7: Urban Principal Arterials
Group 8: Urban Minor Arterials
Group 9: Urban Collectors and Locals

Table C-2.2D(a) Summary of Precision Analysis, Criterion D, Vehicle Classification, 1995

Group	Coefficient of Variation %	Precision %
1	13.7308	10.5928
2	12.9438	9.2588
3	11.7033	105.1478
4	13.1348	118.0096
5	14.7123	15.4421
6	not applicable	not applicable
7	not applicable	not applicable
8	not applicable	not applicable
9	not applicable	not applicable

However, it can be seen from the precision analysis in the Appendix that such a criterion is associated with the worst case of forced grouping of the criteria considered so far. This is readily manifest in the very high values of coefficients of variation.

Adequacy analysis carried out using this data set indicated that large numbers of additional sites are required. This is attributed to the few numbers of ATR sites in most of the groups (the existing number of sites is thinly stretched among the several number of groups). Any recommendation based on the adequacy analysis using this criterion would clearly be excessively expensive and revolutionary, and would thus contravene suggested methods of modifying ATR programs.

Criterion E (Grouping based on a combination of area, regional, peripheral and functional classes)
This study examined the variation of vehicle classification ATR data from the perspective of each ATR site's area, regional and functional classes, and its proximity to state borders. The various groups for this grouping criterion are:

Group 1: Non-peripheral ATRs except Northern Rural Interstates
Group 2: Peripheral ATRs except Northern Rural Interstates
Group 3: Northern Rural Interstates

Table C-2.E(a) shows the summary of results for the precision analysis, while the summary of the adequacy analysis for this criterion is given in Table C-2.E(b). The results show rather high variation and poor precision values, in spite of the fact that there are

several existing ATRs in each of these groups. This suggests that this grouping criterion does a poor job in its attempt to extract patterns based on all four attributes, and therefore is not suitable for grouping vehicle-classification ATRs.

Table C-2.2E(a) Summary of Precision Analysis, Criterion E, Vehicle Classification , 1995

Group	Coefficient of Variation %	Precision %
1	18.1006	12.8233
2	18.8162	21.0428
3	18.5088	54.0549

Table C-2.2E(b) Summary of Adequacy Analysis, Criterion E, Vehicle Classification, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	35	17	18
Group 2	37	10	27
Group 3	36	4	32

Criterion F (Grouping based on a combination of area and functional classes)
Some states have discovered that traffic volume patterns on their roads are adequately captured using a combination of area and functional classes in the following manner:

Group 1: Rural Interstates and Other Principal Arterials
Group 2: Rural Other, i.e., Minor Arterials, Major and Minor Collectors, Locals.
Group 3: Urban Interstates, Other Principal Arterials, and Freeways and Expressways.
Group 4: Urban Other, i.e., Minor Arterials, Major and Minor Collectors, Locals.

Even though this criterion has been found appropriate for traffic volume patterns of some states, this study uses this criterion to examine whether such a criterion would uncover any pattern for vehicle classification data for the state of Indiana.

Table C-2.F(a) shows the summary of results for the precision analysis, while the summary of the adequacy analysis for this criterion is given in Table C-2.2F(b).

Table C-2.2F(a) Summary of Precision Analysis, Criterion F, Vehicle Classification, 1995

Group	Coefficient of Variation %	Precision %
1	16.5507	18.5092
2	19.3174	16.5502
3	16.4580	27.0908
4	n.a.	n.a.

Table C-2.2F(b) Summary of Adequacy Analysis, Criterion F, Vehicle Classification, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	29	13	16
Group 2	38	14	24
Group 3	29	6	23
Group 4	n.a.	1	2

For this criterion, the coefficients of variation for the various groups formed range from 16.5% to 19.3 5, while precision values were between a modest 16.6% and 27%. Compared to results of other criteria, these results are considered average: better than several non-cluster criteria (with the exception of Criteria H and I), yet considerably worse than results using strictly-cluster criteria.

Criterion G (Grouping based on functional classes only)
This grouping criterion was used to determine whether vehicle classification patterns are independent of area class, regional class and peripheral class. The following grouping list was used for the analyses:

Group 1: Interstates
Group 2: Other Freeways and Expressways & Other Principal Arterials
Group 3: Minor Arterials
Group 4: Collectors and Locals

It is observed from Table C-2.2G(a) that the coefficients of variation for each group are generally low, ranging approximately between 7 and 14. The number of ATR stations within each group varies from 2 to 11. Table C-2.2G(b) reveals that the distribution of vehicle classification ATR sites in the State of Indiana is skewed in favor of the high class roads. Both Interstates and Other Principal Arterials each have 11 vehicle classification ATR sites, while Minor Arterials and Collectors each have only 2 sites. Strictly speaking, however, such an examination of ATR distribution is rather simplistic and cannot be the yardstick for measuring appropriateness of distribution of such sites. The precision inherent in data from the ATRs within each group is the correct method of assessing how well the ATR sites are distributed.

Table C-2.2G(a) Summary of Precision Analysis, Criterion G, Vehicle Classification, 1995

Group	Coefficient of Variation %	Precision %
1	14.4292	11.0911
2	21.2351	20.2899
3	8.2249	370.2216
4	19.1908	863.822

Table C-2.2G(b) Summary of Adequacy Analysis, Criterion G, Vehicle Classification, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	29	19	10
Group 2	>40	11	>29
Group 3	12	2	10
Group 4	39	2	37

Criterion H (Grouping based on regional and functional classes)
This criterion groups ATRs on the basis of their regional locations (north versus south), and their functional classes, i.e., high class roads versus lower class roads. This criterion was formulated in response to a suggestion in the *AASHTO Guidelines for Traffic Data Programs* that some states may be able to detect regional patterns in their traffic data. A list of the groups for this criterion is shown below:

Group 1: Northern Interstates
Group 2: Northern Other
Group 3: Southern Interstates
Group 4: Southern Other

Table C-2.2H(a) below shows a summary of the precision analysis for this grouping criterion. This table shows that grouping the vehicle classification ATRs on the basis of their regional and functional classes provides a relatively good picture.

Table C-2.2H(a) Summary of Precision Analysis, Criterion H, Vehicle Classification, 1995

Group	Coefficient of Variation %	Precision %
1	14.4365	13.7939
2	15.2743	44.6086
3	11.8716	13.2764
4	12.7498	20.9869

Table C-2.2H(b) Summary of Adequacy Analysis, Criterion H, Vehicle Classification, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	24	12	12
Group 2	27	7	20
Group 3	19	9	10
Group 4	20	6	14

Criterion I (Grouping based on peripheral and functional classes)
It is envisaged that the percentage of commercial vehicles in highway traffic at areas near the state boundaries may differ from that in the interior of the state. This possibility was

examined by formulating a criterion that takes the peripheral location of ATRs into consideration, in addition to their functional classes. The group list that was drawn for analyzing such a criterion is as follows:

Group 1: Peripheral Interstates
Group 2: Non-peripheral Interstates
Group 3: Peripheral Other
Group 4: Non-peripheral Other

The results obtained for this grouping criterion indicated that there may indeed be some validity in the assumption that vehicle classification on a road, measured in terms of percent commercial vehicles, is influenced by whether the road is near a state border as well as by its functional class. Variations of data units within groups were quite low, and precision values were relatively good. Furthermore, the adequacy analysis showed that relatively few additional sites were needed. This result is similar to that obtained for criterion H which considers regional and functional classes only. The average precision of existing sites and adequacy of sites for criteria H and I are better than those for most of the other criteria considered in the study, with the exception of those based strictly on the results of cluster analysis.

Table C-2.2I(a) Summary of Precision Analysis, Criterion I, Vehicle Classification, 1995

Group	Coefficient of Variation %	Precision %
1	15.8093	19.5574
2	9.7819	18.3858
3	21.2706	29.8025
4	12.5081	13.9881

Table C-2.2I(b) Summary of Adequacy Analysis, Criterion I, Vehicle Classification , 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	28	11	17
Group 2	15	7	8
Group 3	>40	7	>33
Group 4	20	9	11

Criterion J (Grouping based only on regional locations)
Grouping ATR sites on the basis of their regional locations only was carried out and examined to detect the presence of any vehicle classification patterns based solely on their regional locations. Using this criterion, the ATRs were grouped as shown below:

Group 1: Northwestern
Group 2: Northeastern
Group 3: Southwestern
Group 4: Southeastern

Group 5: Central

A map and list showing the location of counties and ATRs with respect to these regional groupings, are provided in Appendices C-4.3 and C-4.4, respectively.

Table C-2.2J(a) Summary of Precision Analysis, Criterion J, Vehicle Classification, 1995

Group	Coefficient of Variation %	Precision %
1	17.7223	18.2139
2	12.2115	22.0194
3	12.0447	14.9003
4	21.1802	948.6845
5	15.6753	15.3687

Table C-2.2J(b) Summary of Adequacy Analysis, Criterion J, Vehicle Classification, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	33	10	23
Group 2	19	5	14
Group 3	19	9	10
Group 4	>30	4	>36
Group 5	12	6	6

The results show rather high variation and corresponding poor precision among data units, and this reflects the fact that adoption of this criterion for grouping classification ATRs would indeed be a poor choice.

C-2.3 Summary of results and discussion

The table below shows the overall summary of the results of precision analysis for all criteria:

Table C-2.3a Summary of precision analysis

Criterion	Weighted Average Coefficient of Variation (%)	Weighted Average Precision (%)
A (Strictly cluster, unspecified n)	3.5573	4.3233
B1 (Strictly cluster, n=3)	3.9363	4.8543
B2 (Strictly cluster, n=4)	3.5573	4.3233
B3 (Strictly cluster, n=5)	2.5876	3.6551
B4 (Strictly cluster, n=6)	1.9412	3.9310
C (Old INDOT grouping)	16.8630	69.3030
E (Area/functional/peripheral)	18.2143	20.8733
F (Area/functional classes)	17.7003	19.1676
G (Functional classes only)	17.0182	87.8787
H (regional/functional classes)	14.4409	18.4559
I (peripheral /functional classes)	14.8235	19.9706
J (regional classes only)	14.7140	19.9373

Discussion of results of the cluster analysis for classification ATRs

The clustering procedure in which the desired number of clusters was not specifically input yielded 4 clusters. Details of the results are provided as Appendices A.2.3 (i) to (v). In cluster group 1, ATRs on Other Arterials and those in the Northern region of the State show a very strong domination. For this cluster group, Northern Rural Other Arterials may aptly represent the average attribute.

The next cluster group on this table shows Urban and Interstate ATRs as having a fair and strong domination respectively. Also, Northern ATRs show a fairly strong dominance, while ATRs in non-peripheral counties constitute only a weak majority. Therefore, "Northern Urban Interstates" may be the appropriate description for this group.

The 3rd cluster group, which consists of 8 ATRs, shows strong domination by Rural and Other Arterial ATRS, while Southern and peripheral ATRs form a fair and weak majority

respectively. This is suggestive of the "Southern Rural Other Arterial" description for ATRs in this group. In the 4th cluster, the Rural attribute is weak in its dominance, while the Interstate ATRs form a very convincing majority. Southern and non-peripheral ATRs also form weak majorities. In conclusion, it can be seen that the regional (North/South) and functional class attributes play a major role in defining the groups formed by cluster analysis, and yield a grouping that closely resembles that of Criterion H, .i.e., Northern Interstates, Northern Other Arterials and Collectors, Southern Interstates, and Southern Other Arterials and Collectors.

Overall discussion

From the results of cluster, precision and adequacy analyses, it is clear that Criterion H provides the best non-cluster seasonal group list for vehicle classification. This criterion has the lowest values of variation within its groups. Also, the average precision values in each group of this criterion, even though quite poor, are the best among the non-cluster grouping criteria.

For criterion H, a total of 56 additional classification ATRs are needed. In the subsequent pages, the best location of these additional sites, for each seasonal factor group within this criterion, is analyzed and presented. The analysis considers a variety of factors that include NHS segments, HPMS sample sections, proximity to state borders, and the possibility of upgrading equipment at sites used by other count programs. The weights attached to each of these factors was obtained with consultation with various contact persons at INDOT.

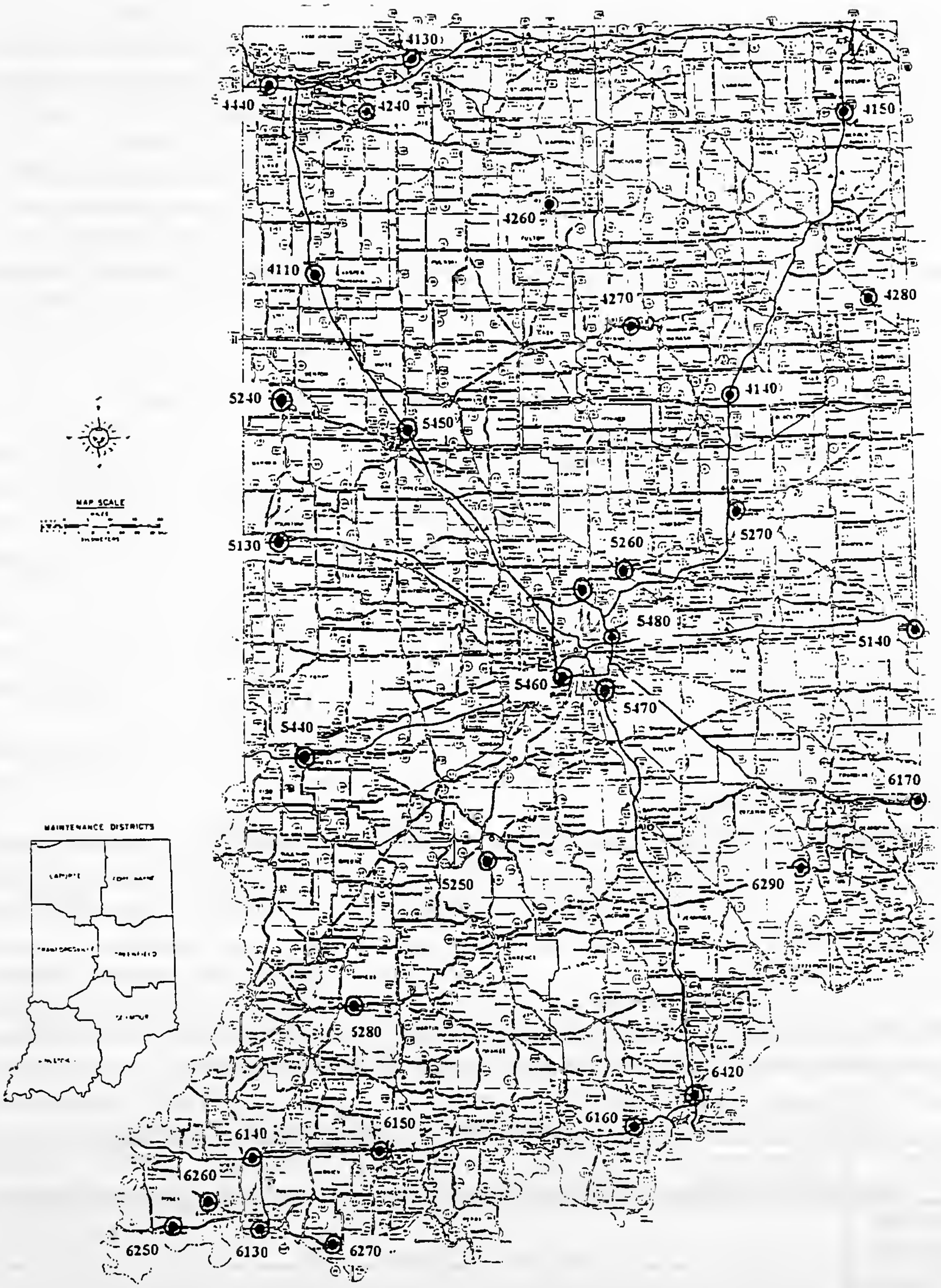


Figure C-2.3
Map of the State of Indiana showing locations of existing vehicle classification ATRs

C-2.4 Distribution of additional ATRs

As has already been discussed in section C (g).2.1 of this document, the locations of additional ATR sites in each group, will be selected from several potential sites. Potential sites will include existing sites used for other count programs, suitable "old" sites, and sites chosen based on engineering judgment. Points will be allocated to each site depending upon whether (or how well) each of theses sites meet a given set of factors such as location of the potential site on the NHS. To each factor point thus allocated to each potential site a weight will be applied to reflect the relative importance of that factor. Finally, all weighted points for each potential will be summed up, and the potential site with the highest sum of points is the first choice candidate for an additional ATR site.

Table C-2.4 Weights attached to various factors for distribution of additional vehicle-classification ATRs

Class Factor	Northern Interstates	Northern Other	Southern Interstates	Southern Other
1. Location on NHS segment (wf1)	15%	15%	15%	15%
2. Proximity to state border (wf2)	15%	5%	15%	5%
3. Location on HPMS sample section (wf3)	5%	10%	5%	10%
4. Geographical distribution (wf4)	35%	35%	35%	35%
5. Possibility of upgrading existing equipment (wf5)	30%	35%	30%	35%
TOTAL	100%	100%	100%	100%

From the adequacy analysis for the grouping criterion selected for vehicle classification, the additional number of sites needed are shown on the following table:

Table C-2.5 Distribution of existing and additional sites and potential sites

Group	Minimum number of sites needed	Existing number of sites	Number of additional sites needed	Number of potential sites considered
Northern Interstates	24	12	12	15
Northern Other	27	7	20	31
Southern Interstates	19	9	10	12
Southern Other	20	6	14	33

C-2.4.1 Group 1 *(Northern Interstates)*

C-2.4.1.1 NHS locations: As has been indicated on Table C-2.4.1(a), all the potential locations lie on the National Highway System, and are therefore allocated a point of 1 each.

C-2.4.1.2 Proximity to border: Only 4 of the 12 potential sites are considered as being in close proximity to the border, and are thus assigned points of 1.

C-2.4.1.3 Location on the HPMS: all the potential locations lie on an HPMS segment, and are therefore allocated a point of 1 each.

C-2.4.1.4 Possibility of upgrading: Of the 12 sites under consideration, 7 have existing equipment used for other count programs, and these sites may be upgraded to classification status.

C-2.4.1.5 Geographical distribution: The minimum distances, in miles, of potential vehicle-classification ATR locations (P), from existing vehicle-classification ATR sites (E), are as follows:

min[P(1)E(j)] = 2.96 min[P(6)E(j)] = 10.36 min[P(11)E(j)] = 20.70

min[P(2)E(j)] = 23.68 min[P(7)E(j)] = 30.12 min[P(12)E(j)] = 0.74

min[P(3)E(j)] = 11.98 min[P(8)E(j)] = 22.94 min[P(13)E(j)] = 35.52

min[P(4)E(j)] = 14.8 min[P(9)E(j)] = 73.26 min[P(14)E(j)] = 25.16

min[P(5)E(j)] = 1.48 min[P(10)E(j)] = 4.44 min[P(15)E(j)] = 9.68

Maximum of the minimum distances = 73.26 miles. This corresponds to P(9), the potential classification ATR location on I90/80 at the South Bend area. For determining the rest of choices ATR locations, two methods were used:

Option1: Locating all k facilities at one time.

Using this option, the hierarchy of choices follows the results shown above: the ATR that corresponds to the maximum of the nearest (minimum distances from) existing classification ATRs is the best choice, and the ATR with the least nearest distance is the worst choice. The rest of the sites are assigned ranks based on the magnitude of their nearest distances from existing classification ATR equipment.

The resulting ranks for each potential location using this option, are shown on Table 5.2.13(a) below:

Table C-2.4.1.5 (a)

Choice ranking of potential locations on basis of geographical distribution only, for Northern Interstates, Option 1 (location of all *n* facilities at a time)

Choice	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th
Potential site ID	P9	P13	P7	P14	P2	P3	P8	P11	P15	P4	P6	P10	P1	P5	P12

Option 2: Location of 1 facility at a time, *n* times

In this method, the first selected site is assigned the status of an existing classification ATR, and the minimum distances of potential ATR to nearest existing ATRs are re-computed all over again. With this revised network, the best ATR location (one that corresponds to the maximum distance to the nearest existing classification ATR) is selected as the second-ranked best choice. This process continues until all the potential ATRs locations are ranked.

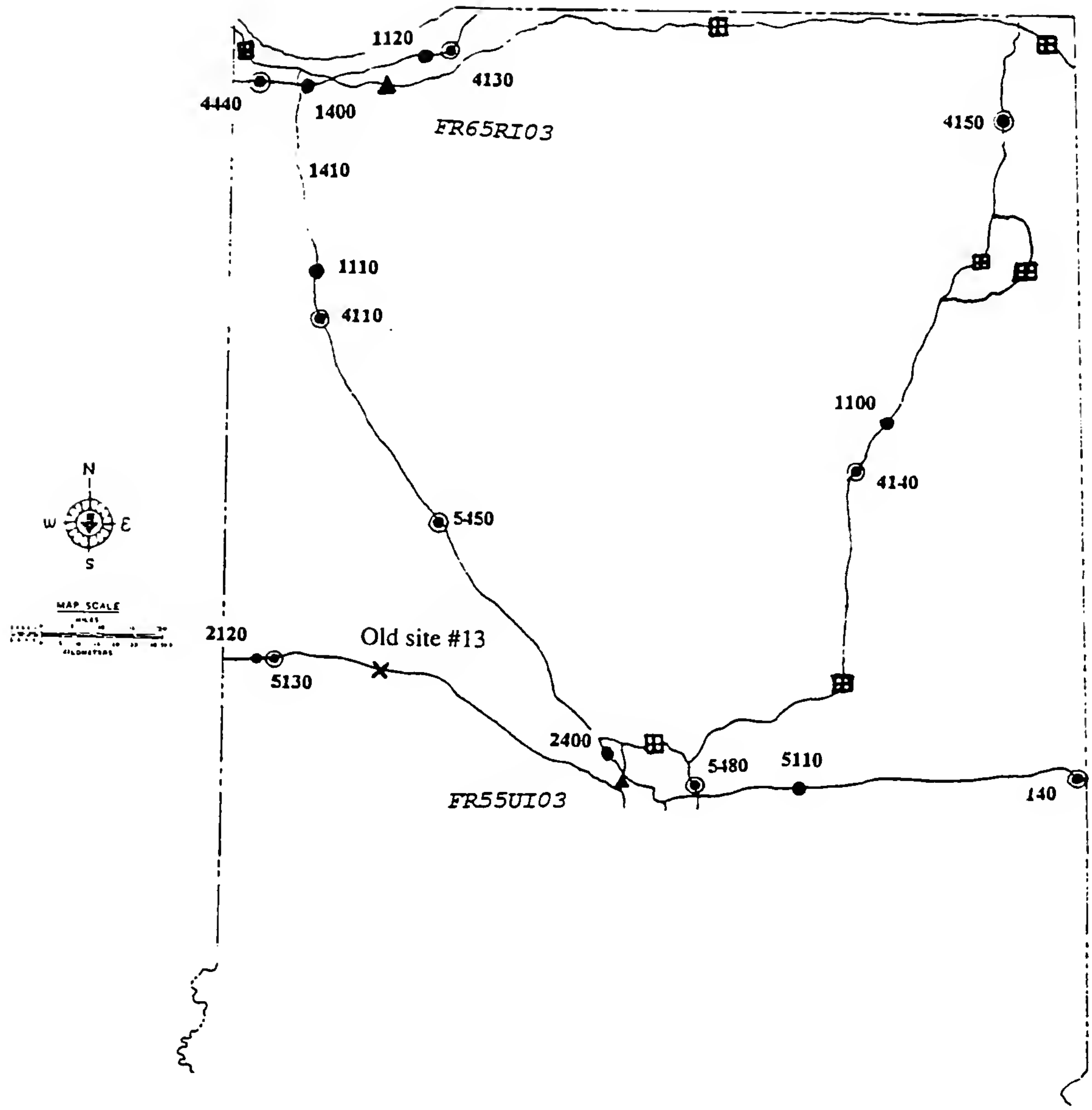
On the basis of this option, the resulting choices are shown below:

Table C-2.4.1.5(b)

Choice ranking of potential locations on basis of geographical distribution only, for Northern Interstates, Option 2 (location of 1 facility at a time, for *n* times)

Choice	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th
Potential site ID	P9	P13	P97	P2	P14	P3	P8	P11	P15	P4	P6	P10	P1	P5	P12

It is observed that Option 2 gives a slightly different ranking than did Option 1. Option 2 will be used for the rest of the analysis because it provides a better reflection of the evolutionary and incremental nature of ATR programs in most states. Very often development of ATR programs are often phased out over a considerable period of time, rather than having a massive sudden change in the program structure.



LEGEND
a) Existing vehicle classification ATR sites
WIM stations
b) Potential vehicle classification ATR sites
Telemetry station
Old monitoring site
Location based on engineering judgment
Speed monitoring site

Figure C-2.4.1
Map of Northern Interstate Roads in the State of Indiana showing locations of existing and potential classification ATR locations

Table C-2.4.1(a)
Evaluation of potential locations for classification ATRs
Group1: *Northern Interstates*
Part 1: Allocation of points to potential sites

Factor / Potential site P(k)	Location on NHS (pf1)	Proximity to state border (pf2)	Location on HPMS sample (pf3)	Geographical location (pf4)	Possibility of upgrading (pf5)
P1: Telemetry 2120	1	1	1	0.13	1
P2: Old site #13	1	0	1	0.73	1
P3: Telemetry 2400	1	0	1	0.60	1
P4: Suggested site on I-465, near Indy	1	0	1	0.33	0
P5: Old site #01	1	0	1	0.07	0
P6: Telemetry 1100	1	0	1	0.27	1
P7: Suggested site on I-469, Ft. Wayne	1	0	1	0.80	0
P8: Suggested site on I-80/90 near Angola	1	1	1	0.53	0
P9: Suggested site on I-80/90, South Bend	1	0	1	1.00	0
P10: Telemetry 1120	1	1	1	0.20	1
P11: Suggested site on I-90, East Chicago	1	1	1	0.47	0
P12: Telemetry 1400	1	0	1	0.00	1
P13: Suggested site on I-69, near Muncie	1	0	1	0.87	0
P14: Suggested site on I-469, Ft. Wayne	1	0	1	0.67	0
P15: Speed site FR55UI03, on I-465	1	0	1	0.40	1

Table C-2.4.1(b)
Evaluation of potential locations for classification ATRs
Seasonal Factor Group1: Northern Interstates
Part 2: Application of weights to points, and ranking of potential sites

Factor / Potential site, P(k)	Location on NHS (pf1*wf1)	Proximity to state border (pf2*wf2)	Location on HPMS sample (pf3*wf3)	Geographical location (pf4*wf4)	Possibility of upgrading (pf5*wf5)	Total points	Rank
P1: Telemetry 2120	0.15	0.15	0.05	0.05	0.30	0.70	**3**
P2: Old site #13	0.15	0	0	0.26	0	0.41	13
P3: Telemetry 2400	0.15	0	0.05	0.21	0.30	0.71	**2**
P4: Suggested site on I-465, Indy	0.15	0	0.05	0.12	0	0.32	14
P5: Old site #01	0.15	0	0	0.02	0	0.17	15
P6: Telemetry 1100	0.15	0	0.05	0.09	0.30	0.59	**5**
P7: Suggested site on I-469, Ft. Wayne	0.15	0	0.05	0.28	0	0.48	**10**
P8: Suggested site on I-80/90, near Angola	0.15	0.15	0.05	0.19	0	0.54	**7**
P9: Suggested site on I-80/90, South Bend	0.15	0	0.05	0.35	0	0.55	**6**
P10: Telemetry 1120	0.15	0.15	0.05	0.07	0.30	0.72	**1**
P11: Suggested site on I-90, EastChicago	0.15	0.15	0.05	0.16	0	0.51	**8**
P12: Telemetry 1400	0.15	0	0.05	0.00	0.30	0.50	**9**
P13: Suggested site on I-69, near Muncie	0.15	0	0	0.30	0	0.45	**11**
P14: Suggested site on I-69, Ft. Wayne	0.15	0	0.05	0.23	0	0.43	**12**
P15: Speed site FR55UI03, on I-465, near Indy Airport	0.15	0	0.05	0.14	0.30	0.64	**4**

Total points for potential site k, = SUM [pf_i * wf_i], for i= 1 to 5
where pf_i = points "earned" by potential site k with respect to factor i
and wf_i = weight attached to factor i (see Table C-2.4)
The first 12 sites are selected. A list of these sites and their locations on the map, are provided in the "conclusions" section of this document.

C-2.4.2 Group 2 *(Northern Other Freeways and Expressways, Other Principal and Minor Arterials, Collectors and Locals):*

C-2.4.2.1 NHS locations: As has been indicated on Table C-2.4.2(a), 14 of the 31 potential locations lie on the National Highway System, and are therefore allocated a point of 1 each.

C-2.4.2.2 Proximity to border: Only 8 of the 31 potential sites are considered as being in close proximity to the border, and are thus assigned points of 1.

C-2.4.2.3 Location on the HPMS: 19 of the potential locations lie on an HPMS segment, and are therefore allocated a point of 1 each.

C-2.4.2.4 Possibility of upgrading: Of the 31 sites under consideration, only 5 do not have existing equipment used for other count programs, and these sites are assigned a point of 0.

C-2.4.2.5 Geographical distribution: The minimum distances, in miles, of potential vehicle-classification ATR locations (P), from existing vehicle-classification ATR sites (E), are as follows:

min[P(1)E(j)] = 51.06, min[P(2)E(j)] = 41.44, min[P(3)E(j)] = 32.56, min[P(4)E(j)] = 5.92, min[P(5)E(j)] = 13.32, min[P(6)E(j)] = 34.78, min[P(7)E(j)] = 31.05, min[P(8)E(j)] = 12.58, min[P(9)E(j)] = 25.16, min[P(10)E(j)] = 21.46, min[P(11)E(j)] = 23.68, min[P12)E(j)] = 34.04, min[P13)E(j)] = 50.32, min[P14)E(j)] = 36.26, min[P(15)E(j)] = 20.72, min[P(16)E(j)] = 6.66, min[P(17)E(j)] = 28.12, min[P(18)E(j)] = 48.84, min[P(19)E(j)] = 26.63, min[P(20)E(j)] = 22.94, min[P(21)E(j)] = 39.98, min[P(22)E(j)] = 31.82, min[P(23)E(j)] = 4.44, min[P(25)E(j)] = 19.24, min[P(25)E(j)] = 32.56, min[P(26)E(j)] = 37.74, min[P(27)E(j)] = 39.92, min[P(28)E(j)] = 33.30, min[P(29)E(j)] = 12.54, min[P(30)E(j)] = 19.76, and min[P(31)E(j)]= 20.72.

The resulting ranking on the basis of geographical distribution by network analysis, are shown in the table below:

Table C-2.4.2.5 (a)
Choice ranking of potential locations on basis of geographical distribution only, for Northern Other Freeways and Expressways, Other Arterials, and Collectors

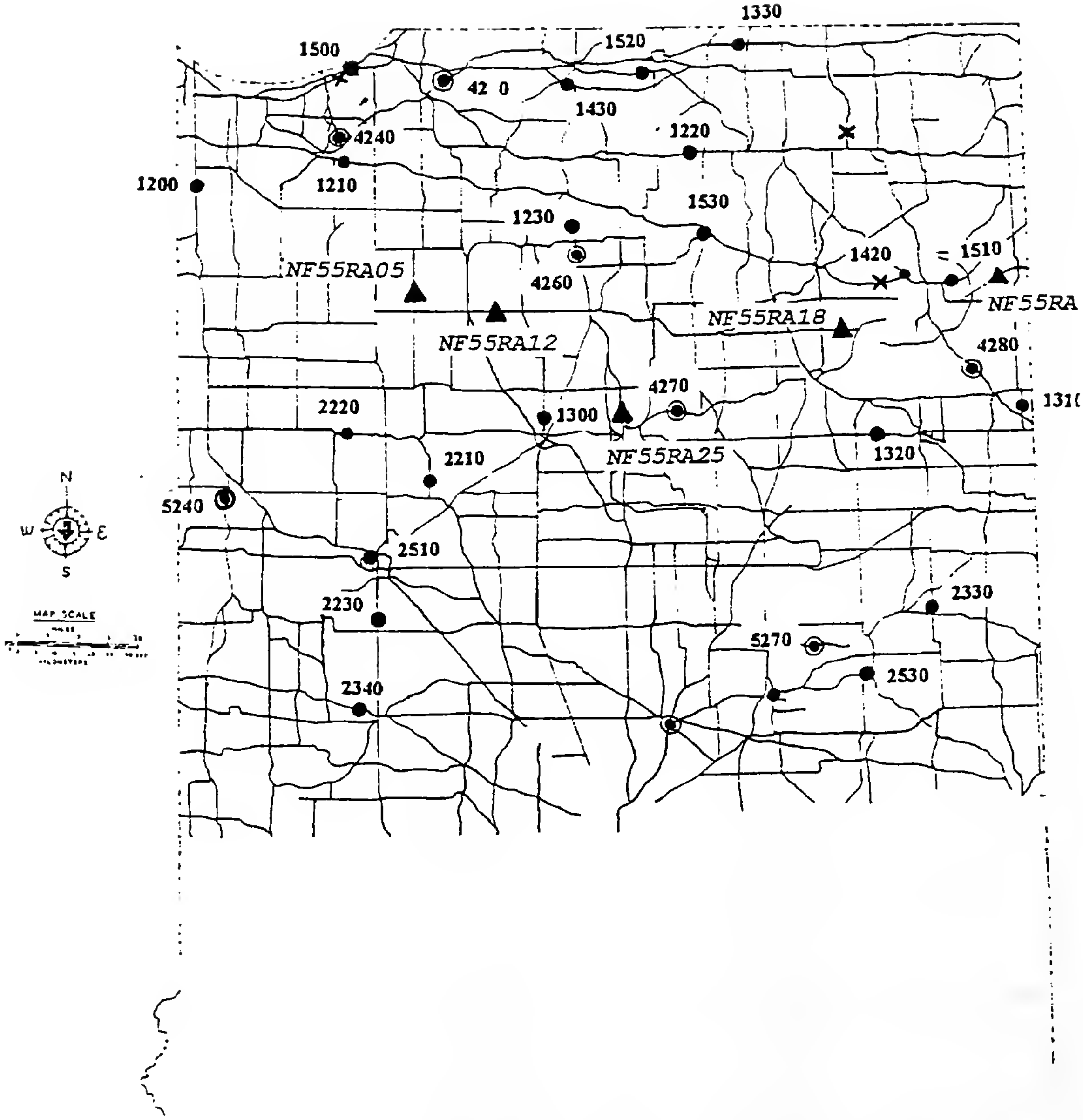
Choice	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
Potential site	P1	P13	P21	P6	P28	P25	P18	P3	P7	P12	P17

Choice	12th	13th	14th	15th	16th	17th	18th	19th	20th	21st	22nd
Potential site	P14	P19	P9	P20	P26	P27	P10	P11	P30	P31	P24

Choice	23rd	24th	25th	26th	27th	28th	29th	30th	31st
Potential site ID	P15	P8	P5	P29	P2	P22	P16	P4	P23

Table C-2.4.2.5 (b)
Example of engendered network changes at each step of network analysis
Group 2: Northern "Other"

Step	Assignment of potential classification ATR P(k) to "existing classification ATR" category	New minimum distances
1.	P(1)	min[P(2)E(j)] = 19.24, min[P(3)E(j)]=31.08 min[P(18)E(j)] = 31.82,
2.	P(13)	min[P(12)E(j)]=29.60 min[P(14)E(j)] = 26.64
3.	P(21)	min[P(22)E(j)] = 8.14, min[P(26)E(j)]=22.20 min[P(27)E(j)] = 28.86
4.	P(6)	none
5.	P(28)	none
6.	P(25)	none
7.	P(18)	min[P(12)E(j)] = 29.53
8.	P(3)	min[P(27)E(j)] = 22.10
9.	P(7)	none
10	P(12)	min[P(11)E(j)] = 17.39
11.	P(17)	none
12.	P(14)	min[P(15)E(j)] = 15.89
13.	P(19)	none
14.	P(9)	min[P(27)E(j)] = 15.91
15.	P(20)	none
16.	P(26)	none
17.	P(27)	none
18.	P(10)	none
19.	P(11)	none
20.	P(30)	none
21.	P(31)	none
22.	P(24)	none
23.	P(11)	none
24.	P(15)	none
25.	P(8)	none
26.	P(5)	none
27.	P(29)	none
28.	P(2)	none
29.	P(22)	none
30.	P(16)	none
31.	P(23)	none



LEGEND

a) Existing vehicle classification ATR sites

◉ WIM stations

b) Potential vehicle classification ATR sites

● Telemetry station

✕ Old monitoring site

⊞ Location based on engineering judgment

▲ Speed monitoring site

Figure C-2.4.2: Map of Northern "Other" Roads in the State of Indiana showing locations of existing and potential classification ATR locations

Table C-2.4.2(a)
Evaluation of potential locations for classification ATRs
Group2: *Northern Other*
Part 1: Allocation of points to potential sites

Factor / Potential site	Location on NHS (pf1)	Proximity to state border (pf2)	Location on HPMS sample (pf3)	Geographical location (pf4)	Possibility of upgrading (pf5)
P1: Telemetry 2340	0	0	0	1.000	1
P2: Telemetry 2230	1	0	1	0.129	1
P3: Telemetry 2510	1	0	1	0.742	1
P4: Telemetry 2500	0	0	0	0.032	0
P5: Telemetry 2530	1	0	1	0.194	1
P6: Telemetry 2330	0	0	0	0.871	1
P7: Telemetry 1320	0	0	1	0.710	1
P8: Telemetry 1310	0	1	0	0.226	1
P9: Telemetry 1510	0	0	0	0.548	1
P10: Telemetry 1420	1	0	1	0.419	1
P11: Telemetry 1530	1	0	1	0.387	1
P12: Telemetry 1220	0	0	0	0.677	1
P13: Telemetry 1330	0	1	0	0.935	1
P14: Telemetry 1520	1	1	1	0.613	1
P15: Telemetry 1430	1	1	1	0.258	1
P16: Telemetry 1230	1	0	1	0.065	1
P17: Telemetry 1300	0	0	0	0.645	1
P18: Old site # 1A	0	0	1	0.774	0

Table C-2.4.2(a), continued
Evaluation of potential locations for classification ATRs
Group2: *Northern Other*
Part 1: Allocation of points to potential sites (continued)

Factor / Potential site	Location on NHS (pf1)	Proximity to state border (pf2)	Location on HPMS sample (pf3)	Geographical location (pf4)	Possibility of upgrading (pf5)
P19: Old site # 1B	1	0	1	0.581	0
P20: Speed site NF55RA12	0	0	0	0.516	1
P21: Old site #1C	0	0	0	0.903	0
P22: Speed site NF55RA05	0	0	1	0.097	1
P23: Telemetry 1210	1	0	1	0	1
P24: Old site #	0	1	0	0.290	0
P25: Telemetry 1200	1	1	1	0.806	1
P26: Telemetry 2200	1	0	1	0.483	1
P27: Telemetry 2210	0	0	1	0.452	1
P28: Speed site	0	0	1	0.839	1
P29: Speed site	1	0	1	0.161	1
P30: Telemetry 1500	0	1	0	0.355	1
P31: Speed site	1	1	1	0.332	1

Table C-2.4.2(b)
Evaluation of potential locations for classification ATRs
Group2: *Northern "Other"*
Part 2: Application of weights to points, and ranking of potential sites

Factor / Potential site	Location on NHS (pf1*wf1)	Proximity to state border (pf2*wf2)	Location on HPMS sample (pf3*wf3)	Geographical location (pf4*wf4)	Possibility of upgrading (pf5*wf5)	Total points	Rank
P1: Telemetry 2340	0	0	0	0.35	0.35	0.70	**10**
P2: Telemetry 2230	0.15	0	1	0.05	0.35	0.65	**16**
P3: Telemetry 2510	0.15	0	1	0.26	0.35	0.86	**3**
P4: Telemetry 2500	0	0	0	0.01	0.35	0.36	29
P5: Telemetry 2530	0	0	1	0.07	0.35	0.67	**13**
P6: Telemetry 2330	0	0	0	0.30	0.35	0.65	**15**
P7: Telemetry 1320	0	0	1	0.25	0.35	0.70	**11**
P8: Telemetry 1310	0	0.05	0	0.08	0.35	0.48	25
P9: Telemetry 1510	0	0	0	0.19	0.35	0.54	21
P10: Telemetry 1420	0.15	0	0.10	0.15	0.35	0.75	**6**
P11: Telemetry 1530	0.15	0	0.10	0.14	0.35	0.74	**7**
P12: Telemetry 1220	0	0	0	0.24	0.35	0.59	**20**
P13: Telemetry 1330	0	0.05	0	0.33	0.35	0.73	**8**
P14: Telemetry 1520	0.15	0.05	0.10	0.21	0.35	0.96	**1**
P15: Telemetry 1430	0.15	0.05	0.10	0.09	0.35	0.84	**4**
P16: Telemetry 1230	0.15	0	0.10	0.02	0.35	0.62	**17**
P17: Telemetry 1300	0	0	0	0.23	0.35	0.53	23
P18: Old site #1A	0	0	0.10	0.27	0	0.37	28

Table C-2.4.2(b), continued
Evaluation of potential locations for classification ATRs
Group2: *Northern "Other"*
Part 2: Application of weights to points, and ranking (cont'd)

Factor / Potential site	Location on NHS (pf1*wf1)	Proximity to state border (pf2*wf2)	Location on HPMS sample (pf3*wf3)	Geographical location (pf4*wf4)	Possibility of upgrading (pf5*wf5)	Total points	Rank
P19: Old site #1B	0.15	0	0.10	0.20	0	0.45	27
P20: Speed site NF55RA12	0	0	0	0.18	0.35	0.53	22
P21: Old site	0	0	0	0.32	0	0.32	29
P22: Speed site NF55RA05	0	0	0.10	0.03	0.35	0.48	26
P23: Telemetry 1210	0.15	0	0.10	0	0.35	0.60	**19**
P24: Old site #1C	0	0.05	0	0.10	0	0.15	31
P25: Telemetry 1200	0.15	0.05	0.10	0.28	0.35	0.93	**2**
P26: Telemetry 2220	0.15	0	0.10	0.17	0.35	0.77	**5**
P27: Telemetry 2210	0	0	0.10	0.16	0.35	0.61	**18**
P28: Speed site NF55RA18	0	0	0.10	0.29	0.35	0.69	**12**
P29: Speed site NF55RA25	0.15	0	0.10	0.06	0.35	0.66	**14**
P30: Telemetry 1500	0	0.05	0	0.12	0.35	0.52	24
P31: Speed site NF55RA08	0.15	0.05	0.10	0.12	0.35	0.72	**9**

Total points for potential site k, = SUM [pf_i * wf_i], for i= 1 to 5
where pf_i = points "earned" by potential site k with respect to factor i
and wf_i = weight attached to factor i (see Table C-2.4)
The first 20 sites are selected. A list of these sites and their locations on the map, are provided in the "conclusions" section of this document.

C-2.4.3 Group 3 *(Southern Interstates)*

C-2.4.3.1 NHS locations: Potential locations lie on the National Highway System are allocated a point of 1 each.

C-2.4.3.2 Proximity to border: Only 6 of the 12 potential sites are considered as being in close proximity to the border, and are thus assigned points of 1.

C-2.4.3.3 Location on the HPMS: All but one of the potential locations lie on an HPMS segment, and are therefore allocated a point of 1 each.

C-2.4.3.4 Possibility of upgrading: Of the 12 sites under consideration, only 3 do not have existing equipment used for other count programs, and these sites are assigned a point of 0.

C-2.4.3.5 Geographical distribution: The minimum distances, in miles, of potential vehicle-classification ATR locations (P), from existing vehicle-classification ATR sites (E), are as follows:

min[P(1)E(j)] = 26.64 min[P(6)E(j)] = 20.72 min[P(11)E(j)] = 3.70

min[P(2)E(j)] = 8.14 min[P(7)E(j)] = 44.16 min[P(12)E(j)] = 2.16

min[P(3)E(j)] = 5.18 min[P(8)E(j)] = 10.38

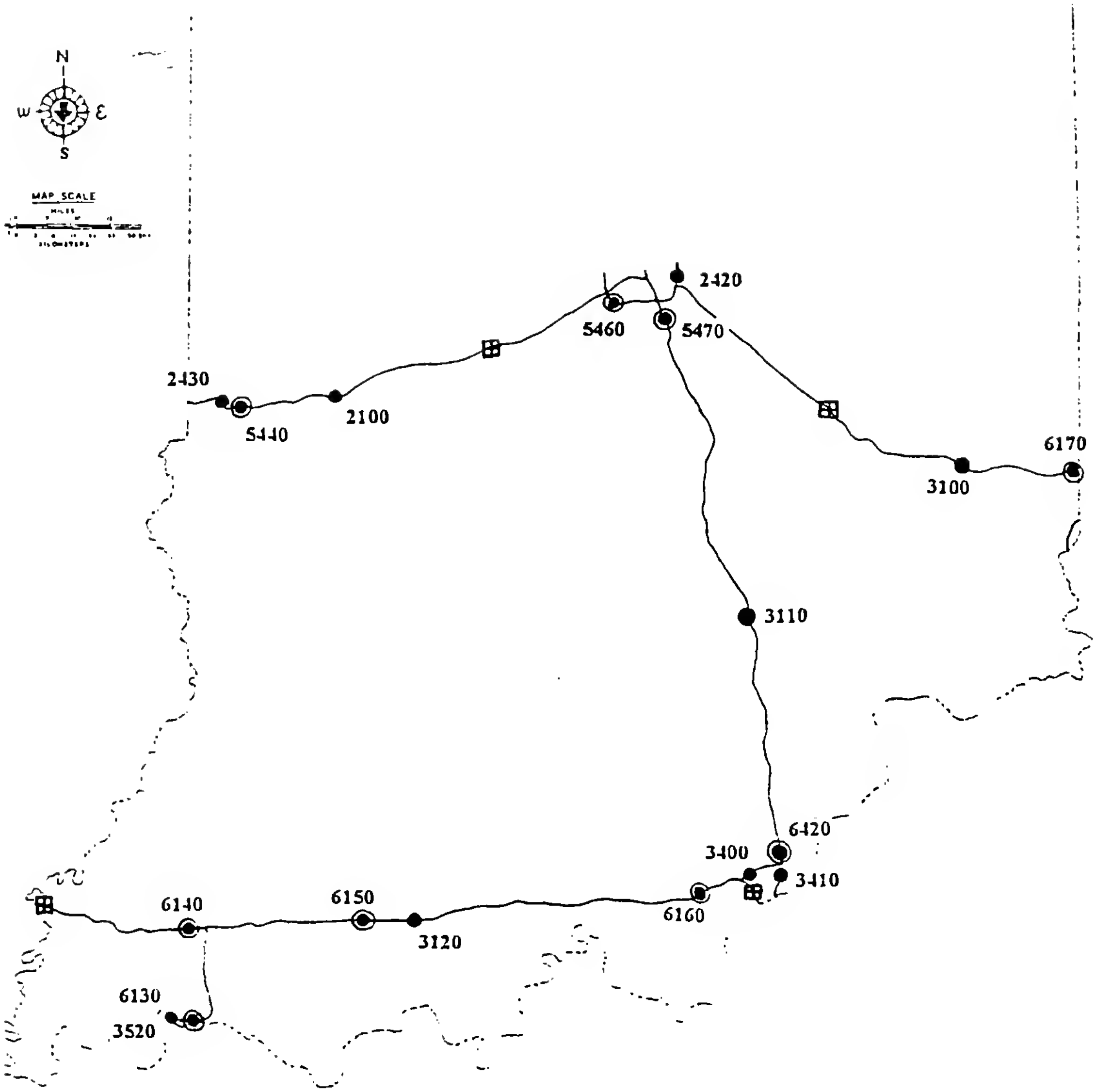
min[P(4)E(j)] = 2.22 min[P(9)E(j)] = 24.42

min[P(5)E(j)] = 40.71 min[P(10)E(j)] = 15.54

Maximum of the minimum distances = 73.26 miles. This corresponds to P(9), the potential classification ATR location on I-74 near Greensburg in Decatur county. The ranking for the remaining potential locations are shown in Table 5.2.12 below.

Table C-2.4.3.5
Choice ranking of potential locations on basis of geographical distribution only, for Southern Interstates

Choice	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Potential site ID	P9	P13	P7	P14	P2	P3	P8	P11	P15	P4	P6	P10



LEGEND
a) Existing vehicle classification ATR sites
WIM stations
b) Potential vehicle classification ATR sites
Telemetry station
Old monitoring site
Location based on engineering judgment
Speed monitoring site

Figure C-2.4.3- Map of Southern Interstate Roads in the State of Indiana showing locations of existing and potential classification ATR locations

Table C-2.4.3 (a)
Evaluation of potential locations for classification ATRs
Group 3: *Southern Interstates*
Part 1: Allocation of points to potential sites

Factor / Potential site P(k)	Location on NHS (pf1)	Proximity to state border (pf2)	Location on HPMS sample (pf3)	Geographical location (pf4)	Possibility of upgrading (pf5)
P1: Suggested site on I-64 in Posey Co. near Illinois state border	1	1	1	0.75	0
P2: Telemetry 3120	1	0	1	0.33	1
P3: Telemetry 3400	1	1	1	0.25	1
P4: Telemetry 3410	1	1	1	0.08	1
P5: Telemetry 3110	1	0	1	0.83	1
P6: Telemetry 3100	1	1	1	0.58	1
P7: Suggested site on I-74, near Greensburg, Dekalb County	1	0	1	1.00	0
P8: Telemetry 2420	1	0	0	0.42	1
P9: Suggested site on I-70, near Cloverdale in Putnam County	1	0	1	0.67	0
P10: Telemetry 2100	1	0	1	0.50	1
P11: Telemetry 2430	1	1	1	0.17	1
P12: Telemetry 3520	1	1	1	0.00	1

Table C-2.4.3(b)
Evaluation of potential locations for classification ATRs
Group 3: Southern Interstates
Part 2: Application of weights to points, and ranking of potential sites

Factor / Potential site, P(k)	Location on NHS (pf1*wf1)	Proximity to state border (pf2*wf2)	Location on HPMS sample (pf3*wf3)	Geographical location (pf4*wf4)	Possibility of upgrading (pf5*wf5)	Total points	Rank
P1: Suggested site on I-64 in Posey Co. near Illinois state border	0.15	0.15	0.05	0.26	0.30	0.61	**9**
P2: Telemetry 3120	0.15	0	0	0.12	0	0.62	**8**
P3: Telemetry 3400	0.15	0.15	0.05	0.09	0.30	0.74	**3**
P4: Telemetry 3410	0.15	0.15	0.05	0.03	0.30	0.68	**5**
P5: Telemetry 3110	0.15	0	0	0.29	0.30	0.79	**2**
P6: Telemetry 3100	0.15	0.15	0.05	0.20	0.30	0.85	**1**
P7: Suggested site on I-74, near Greensburg, Dekalb County	0.15	0	0.05	0.35	0	0.55	11
P8: Telemetry 2420	0.15	0	0	0.15	0.30	0.60	**10**
P9: Suggested site on I-70, near Cloverdale in Putnam County	0.15	0	0.05	0.23	0	0.43	12
P10: Telemetry 2100	0.15	0	0.05	0.18	0.30	0.68	**6**
P11: Telemetry 2430	0.15	0.15	0.05	0.06	0.30	0.71	**4**
P12: Telemetry 3520	0.15	0.15	0.05	0.00	0.30	0.65	**7**

Total points for potential site k, = SUM [pf_i * wf_i], for i= 1 to 5
where pf_i = points "earned" by potential site k with respect to factor i
and wf_i = weight attached to factor i (see Table C-2.4)

The first 10 sites are selected. A list of these sites and their locations on the map, are provided in the "conclusions" section of this document.

C-2.4.4 Group 4 *(Southern Other Freeways and Expressways, Other Principal and Minor Arterials, Collectors and Locals)*

C-2.4.4.1 NHS locations: Only 12 of the 33 potential locations lie on the National Highway System, and are therefore allocated a point of 1 each.

C-2.4.4.2 Proximity to border: Of the 33 potential sites, only 5 are considered as being in close proximity to the border, and are thus assigned points of 1.

C-2.4.4.3 Location on the HPMS: 19 of the potential locations lie on an HPMS segment, and are therefore allocated a point of 1 each.

C-2.4.4.4 Possibility of upgrading: All but 3 of the 33 sites under consideration have existing equipment used for other count programs, and each of these sites are assigned a point of 1.

C-2.4.4.5 Geographical distribution: The minimum distances, in miles, of potential vehicle-classification ATR locations (P), from existing vehicle-classification ATR sites (E), are as follows:

min[P(1)E(j)] = 11.47
min[P(2)E(j)] = 17.09
min[P(3)E(j)] = 28.89
min[P(4)E(j)] = 25.60
min[P(5)E(j)] = 31.08
min[P(6)E(j)] = 26.05
min[P(7)E(j)] = 53.28
min[P(8)E(j)] = 73.14
min[P(9)E(j)] = 63.38
min[P(10)E(j)] = 51.80
min[P(31)E(j)]= 59.26

min[P(11)E(j)] = 49.58
min[P12)E(j)] = 31.04
min[P13)E(j)] = 22.94
min[P14)E(j)] = 2.22
min[P(15)E(j)] = 44.77
min[P(16)E(j)] = 45.16
min[P(17)E(j)] = 27.38
min[P(18)E(j)] = 0.75
min[P(19)E(j)] = 8.88
min[P(20)E(j)] = 12.58
min[P(32)E(j)] = 63.64

min[P(21)E(j)] = 15.54
min[P(22)E(j)] = 14.80
min[P(23)E(j)] = 45.07
min[P(24)E(j)] = 68.08
min[P(25)E(j)] = 19.26
min[P(26)E(j)] = 26.64
min[P(27)E(j)] = 23.68
min[P(28)E(j)] = 29.60
min[P(29)E(j)] = 69.56
min[P(30)E(j)] = 46.62
min[P(33)E(j)]= 44.10

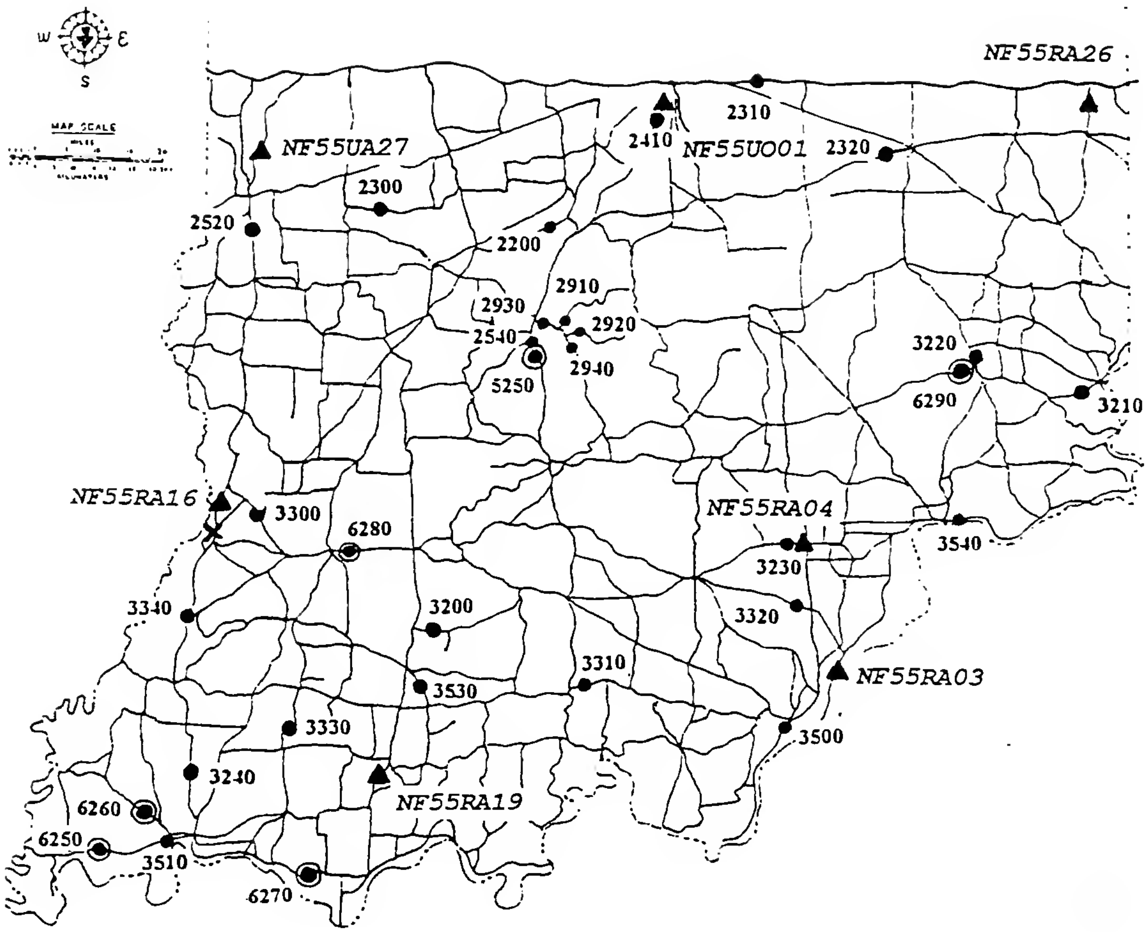
The resulting rankings are shown below:

Table C-2.4.4.5
Choice ranking of potential locations on basis of geographical distribution only, for Southern Other Freeways and Expressways, Other Arterials, and Collectors

Choice	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
Potential site	P31	P5	P13	P29	P2	P23	P10	P1	P21	P28	P24

Choice	12th	13th	14th	15th	16th	17th	18th	19th	20th	21st	22nd
Potential site	P8	P32	P16	P26	P30	P12	P7	P15	P33	P19	P6

Choice	23rd	24th	25th	26th	27th	28th	29th	30th	31st	32d	33rd
Potential site	P3	P17	P25	P4	P9	P11	P18	P20	P14	P22	P27



LEGEND

a) Existing vehicle classification ATR sites
- WIM stations

b) Potential vehicle classification ATR sites
- Telemetry station
- Old monitoring site
- Location based on engineering judgment
- Speed monitoring site

Figure C-2.4.4- Map of Southern "Other" Roads in the State of Indiana showing locations of existing and potential classification ATR locations

Table C-2.4.4(a)
Evaluation of potential locations for classification ATRs
Seasonal Factor Group4: *Southern Other*
Part 1: Allocation of points to potential sites

Factor / Potential site	Location on NHS (pf1)	Proximity to state border (pf2)	Location on HPMS sample (pf3)	Geographical location (pf4)	Possibility of upgrading (pf5)
P1: Telemetry 3510	1	1	1	0.27	1
P2: Telemetry 3240	1	0	1	0.42	1
P3: Telemetry 3330	0	0	0	0.63	1
P4: Speed Site NF55RA19	0	0	1	0.45	1
P5: Telemetry 3530	0	0	1	0.73	1
P6: Telemetry 3200	0	0	0	0.33	1
P7: Telemetry 3310	0	0	0	0.79	1
P8: Telemetry 3500	0	0	0	1.00	1
P9: Telemetry 3320	0	0	0	0.39	1
P10: Telemetry 3230	0	0	1	0.82	1
P11: Speed Site NF55RA04	0	0	1	0.06	1
P12: Telemetry 3540	0	1	0	0.70	1
P13: Telemetry 3210	1	1	1	0.55	1
P14: Telemetry 3220	0	0	0	0.18	1
P15: Telemetry 2320	0	0	0	0.75	1
P16: Speed Site NF55UO01	1	0	1	0	1
P17: Telemetry 2220	0	0	0	0.58	1

Table C-2.4.4(a), continued
Evaluation of potential locations for classification ATRs
Seasonal Factor Group4: *Southern Other*
Part 1: Allocation of points to potential sites

Factor / Potential site	Location on NHS (pf1)	Proximity to state border (pf2)	Location on HPMS sample (pf3)	Geographical location (pf4)	Possibility of upgrading (pf5)
P18: Telemetry 2540	0	0	1	0.03	0
P19: Telemetry 2930	1	0	1	0.24	0
P20: Telemetry 2910	0	0	0	0.18	1
P21: Telemetry 2920	1	0	1	0.36	1
P22: Telemetry 2940	0	0	0	0.09	1
P23: Telemetry 2300	0	0	1	0.85	1
P24: Telemetry 2520	1	0	1	0.30	1
P25: Telemetry 3300	0	0	0	0.48	1
P26: Speed site NF55RA16	1	0	1	0.21	1
P27: Old site on US-41 near Vincennes	1	0	1	0.12	0
P28: Telemetry 3340	1	0	0	0.67	1
P29: Speed site NF55UA27	0	0	1	0.97	1
P30: Telemetry 2310	0	0	0	0.88	1
P31: Speed site NF55RA26	1	1	1	0.91	1
P32: Speed site NF55RA03	0	1	1	0.52	1
P33: Telemetry 2410	1	0	1	0.21	1

Table C-2.4.4(b)
Evaluation of potential locations for classification ATRs
Seasonal Factor Group4: *Southern "Other"*
Part 2: Application of weights to points, and ranking of potential sites

Factor / Potential site	Location on NHS (pf1*wf1)	Proximity to state border (pf2*wf2)	Location on HPMS sample (pf3*wf3)	Geographical location (pf4*wf4)	Possibility of upgrading (pf5*wf5)	Total points	Rank
P1: Telemetry 3510	0.15	0.05	0.10	0.09	0.35	0.74	**8**
P2: Telemetry 3240	0.15	0	0.10	0.15	0.35	0.75	**5**
P3: Telemetry 3330	0	0	0	0.22	0.35	0.57	23
P4: Speed Site NF55RA19	0	0	0	0.16	0.35	0.51	26
P5: Telemetry 3530	0.15	0	0.10	0.26	0.35	0.86	**2**
P6: Telemetry 3200	0	0	0.10	0.12	0.35	0.57	22
P7: Telemetry 3310	0	0	0	0.28	0.35	0.63	18
P8: Telemetry 3500	0	0	0	0.35	0.35	0.70	12
P9: Telemetry 3320	0	0	0	0.14	0.35	0.49	27
P10: Telemetry 3230	0	0	0.10	0.29	0.35	0.74	**7**
P11: Speed Site NF55RA04	0	0	0.10	0.02	0.35	0.47	28
P12: Telemetry 3540	0	0.05	0	0.25	0.35	0.65	17
P13: Telemetry 3210	0	0.05	0.10	0.19	0.35	0.84	**3**
P14: Telemetry 3220	0	0	0	0.05	0.35	0.40	31
P15: Telemetry 2320	0	0	0	0.26	0.35	0.61	19
P16: Speed Site NF55UO01	0.15	0	0.10	0	0.35	0.60	20
P17: Telemetry 2220	0	0	0	0.20	0.35	0.55	24

Table C-2.4.4(b), cont'd
Evaluation of potential locations for classification ATRs
Seasonal Factor Group 4: *Southern "Other"*
Part 2: Application of weights to points, and ranking, cont'd

Factor / Potential site	Location on NHS (pf1*wf1)	Proximity to state border (pf2*wf2)	Location on HPMS sample (pf3*wf3)	Geographical location (pf4*wf4)	Possibility of upgrading (pf5*wf5)	Total points	Rank
P18: Telemetry 2540	0	0	0	0.01	0	0.45	29
P19: Telemetry 2930	0.15	0	0	0.08	0	0.58	21
P20: Telemetry 2910	0	0	0	0.06	0.35	0.41	30
P21: Telemetry 2920	0.15	0	0.10	0.13	0.35	0.73	**9**
P22: Telemetry 2940	0	0	0	0.03	0.35	0.38	32
P23: Telemetry 2300	0	0	0.10	0.30	0.35	0.75	**6**
P24: Telemetry 2520	0.15	0	0.10	0.11	0.35	0.71	**11**
P25: Telemetry 3300	0	0	0	0.17	0.35	0.52	25
P26: Speed site NF55RA16	0.15	0	0.10	0.07	0.35	0.67	**15**
P27: Old site on US-41 near Vincennes	0.15	0	0.10	0.04	0	0.29	33
P28: Telemetry 3340	0.15	0	0	0.23	0.35	0.73	**10**
P29: Speed site NF55UA27	0	0	0.10	0.34	0.35	0.79	**4**
P30: Telemetry 2310	0	0	0	0.31	0.35	0.66	16
P31: Speed site NF55RA26	0.15	0.05	0.10	0.32	0.35	0.97	**1**
P32: Speed site NF55RA03	0	0.05	0.10	0.18	0.35	0.68	**13**
P33: Telemetry 2410	0.15	0	0.10	0.08	0.35	0.78	**14**

Total points for potential site k, = SUM [pf_i * wf_i], for i= 1 to 5
where pf_i = points "earned" by potential site k with respect to factor i
and wf_i = weight attached to factor i (see Table C-2.4)
The first 14 sites are selected. A list of these sites and their locations on the map, are provided in the "conclusions" section of this document.

5.2.14 Suggested modifications to final results for determining new locations for vehicle classification ATRs

Even with the use of the various criteria such as those that have been described and applied in the above analysis, some engineering judgment may be necessary to modify the recommended locations of additional ATRs. It was found that certain potential classification ATR locations that have been chosen lie very "close" to existing classification ATRs. "Closeness" in this context, refers to a distance of less than 2 miles, or a distance over which there is no significant intersection, or both. Recommending a potential ATR site that lies "close" to an existing ATR would clearly lead to redundancy of the new ATR site. There is a fixed number of required ATR sites in each group, and potential sites that would lead to such redundancy were replaced by the next eligible ATR site on the "waiting" list, i.e., just below the cut-off line on the priority ranking table. A list of potential locations that could be replaced is provided as follows:

1. Telemetry 2120, should be replaced by the next eligible potential site in the Northern Interstate group, i.e., Old site #13).

2. Telemetry 1230, should be replaced by the next eligible potential site in the Northern "Other" group, i.e., Telemetry 1510.

3. Telemetry 2430, should be replaced by the next eligible potential site in the Southern Interstate group, i.e., the suggested site on I-74 near Greenburg, Dekalb County, as shown on the figure 5.2.13.4 (a).

Finally, it is important that the priority list be considered as a decision support tool, and not as a rigid set of recommended locations for additional ATRs.

C-3: CONTINUOUS COUNTS FOR TRUCK WEIGHTS

C-3.1 Introduction

Decisions concerning such matters as pavement design, pavement maintenance, equitable tax structures, revenue projections, safety, enforcement, and research require knowledge not only of volumes of traffic using highway facilities and proportion of vehicles of each type, but also the weights of such vehicles. The *Traffic Monitoring Guide* states that, for adequate assessment of pavement life, pavement quality, and the investment levels needed to improve or maintain the systems, it is fundamental to know the range and frequencies of the loads imposed upon the facilities.

Truck weight and vehicle classification data, according to the TMG, are used at the state and national levels in the consideration of transportation policy, the allocation of highway costs and revenue, truck size and weight regulation, the establishment of geometric design criteria related to the size and weight of vehicles, pavement design criteria and selection, and a variety of special administrative, planning, design and research studies. At the state level, truck weight data are used in calculating pavement loadings in single axle equivalents or other comparable procedures, and in bridge loading analyses. Planning, program budgeting, and evaluations, and other administrative studies require statistically reliable axle, vehicle, and total loadings that can be related to operational characteristics, taxation rates, cost responsibility, and enforcement effectiveness.

The TMG does not offer much information about how to analyze the adequacy of truck-weighing ATRs or development of truck-weight seasonal factors. However, the *AASHTO Guidelines for Traffic Data Programs*, on p.57, hints that vehicle weight data may grouped in a manner similar to that of traffic volumes, but the group list for truck weight data collection sites may or may not be the same as that traffic volume or vehicle classification ATRs.

Currently, continuous truck weight measurements are carried out using permanent weigh-in-motion equipment at 34 ATR locations throughout the State of Indiana. (See map in Appendix C - 3 (a)). A sample of weight data generated by some equipment is attached as Appendix C-3 (b).

Currently, there is no program at INDOT to carry out short-term truck weight measurements. However, such a program has been recommended as part this study. With the implementation of the short-term truck weighing program, the selected criterion would have the additional use of providing the appropriate factors by which short-term truck weight measurements may be adjusted into annualized statistics.

Need for the study

The main purpose of examining the existing program of continuous truck weighing measurements is to:

(a) determine the most appropriate criterion for grouping truck-weighing ATRs

(b) establish appropriate factors for annualization of possible future 48-hour truck weight coverage counts, and to provide an indication of spatial and temporal trends in the loading of the highway facilities, and

(c) determine the adequacy of the existing number of truck-weighing ATR stations and the distribution of any additional stations.

The steps used for the analysis are shown in the flow chart provided on page C.4.

Appendix C3.4 shows the results of carrying out cluster analysis on truck volume data obtained at 21 of INDOT's 34 truck-weighing ATRs in the year 1995. Data from only 21 sites were used for the analysis, because only these sites gave reliable data within the period under consideration. MINITAB10 computer software, which was used for the analysis, generated the natural groupings shown in Appendices C-3.4. The cluster analysis was first performed without specifying the number of clusters as an input parameter, then by specifying desired number of clusters in unit increments from 3 to 6.

For each grouping criterion under consideration, the presentation of the results of the precision and adequacy analyses is preceded by a description of the grouping criterion and the rationale for formulating that particular criterion. The discussion on the precision and adequacy analysis covers the existing precision of data obtained by ATR sites in each group, determining how many more sites are needed to improve the precision of data to acceptable levels, and an examination of how well the grouping criterion compares with the natural grouping offered by cluster analysis. From the outcome of these discussions for al the grouping criteria considered, an overall assessment of each grouping criterion is made vis-à-vis other criteria, and the most appropriate criterion is selected. The number of additional sites associated with the chosen criterion is selected as the extra number needed to be installed by INDOT.

C-3.2 Results of analysis and discussion

Criterion A: Grouping strictly based on the results of the cluster procedure where the number of clusters was not specifically entered an input parameter.
The results of clustering monthly truck weight data without specifying the desired number of clusters produced the group list are shown below.

Table C-3.2A(a) Summary of Precision Analysis, Criterion A, Truck Weights, 1995

Group	Coefficient of Variation %	Precision %
1	2.9858	2.4562
2	5.4959	3.0026
3	4.5093	7.5953
4	n.a.	n.a.

Table C-3.2A(b) Summary of Adequacy Analysis, Criterion A, Truck Weights, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional number of ATR sites needed
Group 1	4	6	2 excess
Group 2	4	11	7 excess
Group 3	4	3	1
Group 3	3	1	2

As has been seen from the analyses for the previous count types, the disadvantage of the "strictly cluster" grouping criterion is that the number of clusters (and number of ATRs within each cluster) varies from year to year, thus violating a necessary requirement spelled out by the *AASHTO Guidelines for Traffic Data Programs* that the composition and number of groups should be consistent from year to year. Hence it is recommended that this criterion should not be adopted for use by INDOT to group its truck weighing ATR stations for purposes of seasonal adjustment of future short-term counts.

However, the grouping offered by this criterion may be used as a guide for assessing how well other grouping criteria compare with the "strictly-cluster" grouping.

<u>Criterion B</u> (Grouping strictly based on results of cluster analysis, where the number of clusters is specified)
Using the specified number of clusters as 4, as an input parameter, cluster analysis was carried out on 1995 truck weight data. Specifying 5 and 6 clusters did not yield results very different from that for 4 clusters, and were excluded from further analysis.

B.1 Clustering with number of clusters specified as 3
Details of the results of the cluster procedure in which the number of desired clusters was specified as 4 are provided in Appendix C3.4B1, while Appendix C3.4B1 shows month-by-month details of the precision analysis for this grouping criterion. Table C-3.2B1(a) below shows a summary of the results of the precision analysis.

Table C-3.2B1(a) Summary of Precision Analysis, Criterion B1, Truck Weights, 1995

Group	Coefficient of Variation %	Precision %
1	19.9326	14.6382
2	5.4959	3.0082
3	4.5053	7.5953

Results of precision and adequacy analyses carried out for groups formed on the basis of this criterion are shown in the Appendices C3.2B1 and C3.3B1, while Tables C-3.2B1(a) and C-3.2B1(b) show the summaries of these analyses.

Table C-3.2B1(b)Summary of Adequacy Analysis, Criterion B1, Truck Weights, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	5	10	-
Group 2	>30	5	>25
Group 3	not applicable	1	not applicable
Group 4	24	3	21

As with Criterion A, the disadvantage of this criterion is that the number of clusters are not consistent from year to year, and cannot be used for annualization of short-term statistics.

B.2 Clustering with number of clusters specified as 3, 5 and 6

The results obtained by specifying 4 clusters werte the same as those obtained in Criterion A. Also the results obtained by specifying 4 , 5 and 6 clusters did not present a very different picture.

<u>Criterion C</u> (Grouping based on current INDOT group list)

The current INDOT group list is the current list being used by INDOT for grouping of ATR sites for annualization of 48-hour traffic volume counts, application of growth factors and other analyses that involve grouping. This section of the study seeks to examine how this criterion can be applied to processing of truck weight data. This group list offered by this criterion is as follows:

Group 1: Urban Interstates, Freeways and Expressways
Group 2: Urban Principal Arterials, Minor Arterials, Collectors, and Locals
Group 3: Rural Interstates
Group 4: Rural Principal Arterials and Minor Arterials
Group 5: Rural Collectors and Locals

Table C-3.2C(a) Summary of Precision Analysis, Criterion C, Truck Weights, 1995

Group	Coefficient of Variation %	Precision %
1	12.8384	12.2409
2	n.a.	n.a.
3	16.4897	13.5647
4	25.1026	18.4350
5	1.7668	7.8889

Table C-3.2C(b) Summary of Adequacy Analysis, Criterion C, Truck Weights, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional number of ATR sites needed
Group 1	9	7	2
Group 2	3	1	2
Group 3	13	12	1
Group 4	25	12	13
Group 5	3	2	1

Criterion D (Grouping based on FHWA's HPMS classes)

Appendix G of the *HPMS Field Manual* provides a group list for reporting of data for the nationwide Highway Performance Monitoring System (HPMS). Some researchers have suggested that grouping of ATRs should be done using this grouping criterion. This study seeks to examine the implications of adopting such a criterion for processing of truck weight data. A description of this criterion group list is as follows:

Group 1: Rural Interstates
Group 2: Urban Interstates
Group 3: Urban Freeways and Expressways
Group 4: Rural Principal Arterials
Group 5: Rural Minor Arterials
Group 6: Rural Collectors and Locals
Group 7: Urban Principal Arterials
Group 8: Urban Minor Arterials
Group 9: Urban Collectors and Locals

From a first glance, the group list offered by this criterion seems to be most appropriate because it would make it possible for traffic data analysts to obtain a view of the variation of truck data patterns across a relatively broad spectrum of road functional classes. Furthermore, it would provide unique seasonal adjustment factors for annualization of short-term truck weight counts for each of these groups.

Even though such a grouping criterion seems ideal, it is plagued with extremely high coefficients of variation and very poor precision values, as seen from Table C-3.D(a).

Table C-3.2D(a) Summary of Precision Analysis, Criterion D, Truck Weights, 1995

Group	Coefficient of Variation %	Precision %
1	16.4897	13.3647
2	13.4724	11.0827
3	n.a.	n.a.
4	3.7218	16.6166
5	3.7885	3.6122
6	n.a.	n.a.
7	n.a.	n.a.
8	n.a.	n.a.
9	n.a.	n.a.

From Table C-3.2D(b), it is seen that large numbers of additional sites are required for each group. This is attributed to the large number of groups and subsequent few numbers of ATR sites in most groups. In all, over 50 additional truck weighing ATR sites would be required if this grouping criterion is selected. Implementing this would be excessively expensive and clearly unsuitable.

Table C-3.2D(b) Summary of Adequacy Analysis, Criterion D, Truck Weights, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional number of ATR sites needed
Group 1	13	12	1
Group 2	9	10	1 ecess
Group 3	3	2	1
Group 4	3	2	1
Group 5	4	7	3 excess
Group 6	3	0	3
Group 7	3	0	3
Group 8	3	0	3
Group 9	3	0	3

Criterion F (Grouping based on a combination of area and functional classes)
The suitability of using a grouping criterion to analyze truck weight data based on area and functional classes in the manner shown in the list below, was examined.

Group 1: Rural Interstates and Other Principal Arterials
Group 2: Rural Other, i.e., Minor Arterials, Major and Minor Collectors, Locals.
Group 3: Urban Interstates, Other Principal Arterials, and Freeways and Expressways.
Group 4: Urban Other, i.e., Minor Arterials, Major and Minor Collectors, Locals.

Table C-3.2F(a) shows the summary of results for the precision analysis, while the summary of the adequacy analysis for this criterion is given in Table C-3.F(b).

Table C-3.2F(a) Summary of Precision Analysis, Criterion F, Truck Weights, 1995

Group	Coefficient of Variation %	Precision %
1	16.4897	13.5676
2	29.8444	18.2393
3	4.7444	4.5235
4	n.a.	n.a.

Table C-3.2F(b) Summary of Adequacy Analysis, Criterion F, Truck Weights, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	13	12	1
Group 2	35	14	21
Group 3	4	7	3 excess
Group 4	3	1	2

Criterion G (Grouping based on functional classes only)
This grouping criterion was used to determine whether truck weight data patterns are only dependent on functional class and are thus not influenced by area class, regional class and peripheral class. The following grouping list was used for the analyses:

Group 1: Interstates
Group 2: Other Principal Arterials, Freeways and Expressways
Group 3: Minor Arterials
Group 4: Collectors and Locals

It is observed from Table C-3.2G(a) that the coefficients of variation for each group is relatively low, compared to within-group variation of other truck weight grouping criteria. The average coefficient of variation is about 16%.

Table C-3.2G(a) Summary of Precision Analysis, Criterion G, Truck Weights, 1995

Group	Coefficient of Variation %	Precision %
1	12.2557	6.6957
2	12.8446	9.4328
3	n.a.	n.a.
4	3.3729	15.0588

Table C-3.2G(b) Summary of Adequacy Analysis, Criterion G, Truck Weights, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	9	19	10 excess
Group 2	9	11	2 excess
Group 3	3	2	1
Group 4	4	2	2

Criterion H (Grouping based on regional and functional classes)
The possibility that truck weight data is patterned according to regional locations of the state and the road functional classes was investigated. To do this, a grouping criterion that groups ATRs on the basis of their regional locations (north versus south) and their functional classes was formulated as follows:

Group 1: Northern Interstates, Freeways and Expressways
Group 2: Northern Other
Group 3: Southern Interstates, Freeways and Expressways
Group 4: Southern Other

Table C-3.2H(a) shows a summary of the precision analysis for this grouping criterion.

Table C-3.2H(a) Summary of Precision Analysis, Criterion H, Truck Weights, 1995

Group	Coefficient of Variation %	Precision %
1	14.1911	9.5078
2	3.9314	6.6271
3	35.6087	33.9514
4	20.8413	19.8713

Table C-3.2H(b) Summary of Adequacy Analysis, Criterion H, Truck Weights, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	9	12	3 excess
Group 2	3	7	4 excess
Group 3	>40	9	>31
Group 4	19	6	13

<u>Criterion I</u> (Grouping based on peripheral and functional classes)
The following group list was formulated and analyzed to examine whether any patterns in truck weight could be revealed in relation to the peripheral (or otherwise) location of the truck weight ATRs.

Group 1: Peripheral Interstates
Group 2: Non-peripheral Interstates
Group 3: Peripheral Other
Group 4: Non-peripheral Other

Table C-3.2I(a) Summary of Precision Analysis, Criterion I, Truck Weights, 1995

Group	Coefficient of Variation %	Precision %
1	6.3158	6.0218
2	16.0418	13.1963
3	31.3276	25.7707
4	24.1983	28.4693

Table C-3.2I(b) Summary of Adequacy Analysis, Criterion I, Truck Weights, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	5	12	7 excess
Group 2	12	7	5
Group 3	39	7	32
Group 4	34	8	16

Criterion J (Grouping based only on regional locations)
To identify any pattern in truck weight data based solely on regional location, the following group list was analyzed:

Group 1: Northwestern
Group 2: Northeastern
Group 3: Southwestern
Group 4: Southeastern
Group 5: Central

A map and list showing the location of counties and ATRs with respect to these regional groupings, are provided in Appendices C4.3 and C4.4 respectively. These results also show rather high variation and poor precision.

Table C-3.2J(a) Summary of Precision Analysis, Criterion J, Truck Weights, 1995

Group	Coefficient of Variation %	Precision %
1	33.7321	32.1622
2	22.7131	26.7219
3	18.9945	15.6353
4	9.3298	41.6545
5	11.5739	13.6167

Table C-3.2J(b) Summary of Adequacy Analysis, Criterion J, Truck Weights, 1995

Group	Required number of ATR sites	Existing number of ATR sites	Additional ATR sites needed
Group 1	40	9	31
Group 2	21	6	15
Group 3	16	10	6
Group 4	7	4	3
Group 5	8	5	3

C-3.3 Summary of results and discussion

The table below shows the overall summary of the results of precision analysis for all criteria:

Table C-3.3 Summary of precision analysis

Criterion	Weighted Average Coefficient of Variation (%)	Weighted Average Precision (%)
A (Strictly cluster, unspecified n)	4.3762	3.3571
B1 (Strictly cluster, n=3)	10.1264	7.5210
B2 (Strictly cluster, n=4)	4.3762	3.3571
B3 (Strictly cluster, n=5)	3.7410	3.7275
B4 (Strictly cluster, n=6)	3.3736	3.5105
C (Old INDOT grouping)	17.0770	14.3915
D (FHWA HPMS grouping)	10.8684	10.4947
E (Area/functional/peripheral)	23.0571	13.9762
F (Area/functional classes)	19.1513	13.3913
G (Functional classes only)	**12.2556**	**8.7539**
H (regional/functional classes)	19.2381	17.4286
I (peripheral /functional classes)	19.6667	24.3694
J (regional classes only)	20.9024	24.2381

Discussion of the results of cluster analysis for truck weight ATRs

The "unspecified number" cluster procedure results yielded were similar to that of Criterion B1 (only three clusters specified) and identical to Criterion B2 (4 clusters specified), as can be seen on Tables 8.3.3C (i) to (v). In all of these three cases, Rural Other Principal Arterials formed a strong majority in the first cluster that was formed. The second cluster was dominated by Rural Interstates. The third cluster had only 3 ATRs, for this cluster group, Northern Rural Collectors appeared to be the dominant attribute. For criteria A and B2, the fourth cluster consisted of only 1 ATR, i.e., Laporte 4250, which is a Rural Minor Arterial in the Northeastern peripheral region. The only unique attribute of this "outcast" ATR is that it belongs to the Minor Arterial class, and may be considered as the sole representative of hat functional class.

If the effect of regional and peripheral attributes are ignored (because they do not form strong majorities in most of the cluster groups), functional classes alone may be considered to be the attribute that most significantly addresses the composition of the group formed by the cluster procedure. In this respect, Criterion H may be selected as the criterion which is best corroborated by the cluster analysis.

Overall discussion
It is obvious from the precision, adequacy and cluster analyses that Criterion G offers the most appropriate seasonal group list for truck weights. Compared to the other criteria, this criterion has the lowest average coefficient of variation and the best average and individual precision values within its groups. Analysis of adequacy of truck weight ATR (WIM) sites based on this criterion showed that about 3 additional sites are needed to improve the precision values of data. The table below shows the distribution of additional truck weight ATR sites among the various seasonal groups provided by the selected criterion.

The reliability level recommended in the Traffic Monitoring Guide for traffic volume data is 10 percent precision with 95 percent confidence, or "95-10", for each individual seasonal group. The TMG is silent on the precision requirement for truck weight data. However, the Guide states that "A precision of 10 percent can be established with a high confidence level or low confidence level." The adequacy analysis for truck weight ATRs was carried out using a wider confidence interval of "90-10", i.e., 90 percent confidence. This precision reflected the desired accuracy of truck-weight data indicated by the main users of truck weight data, i.e., the Pavement Management System. The meaning of the "90-10" precision requirement is that, out of every 100 truck weight measurements, 90 are expected to fall within of ± 10 % of the true value.

C-3.4 Distribution of additional ATRs

INDOT has indicated preference for focusing truck-weighing activities on Interstates. Therefore, the study went on to assign the 3 additional sites required to Interstates and determined the best three locations for truck-weighing ATRs (WIMs) on the Interstate road network in the State of Indiana.

Factors that were considered in the selection of sites for additional truck weight ATRs included segments of the National Highway System (NHS), geographical distribution, proximity to state borders, and possibility of upgrading equipment at existing sites (used for other count programs) to truck-weighing capabilities. Potential ATR locations on HPMS sample sections were not specifically considered, because the INDOT contact persons stated that truck weights for HPMS is currently not a reporting requirement, and preferred that this factor be excluded from the analysis for this count type. The table below shows the weights attached by various INDOT contact persons, to various factors considered in the location analysis for additional truck weight ATRs.

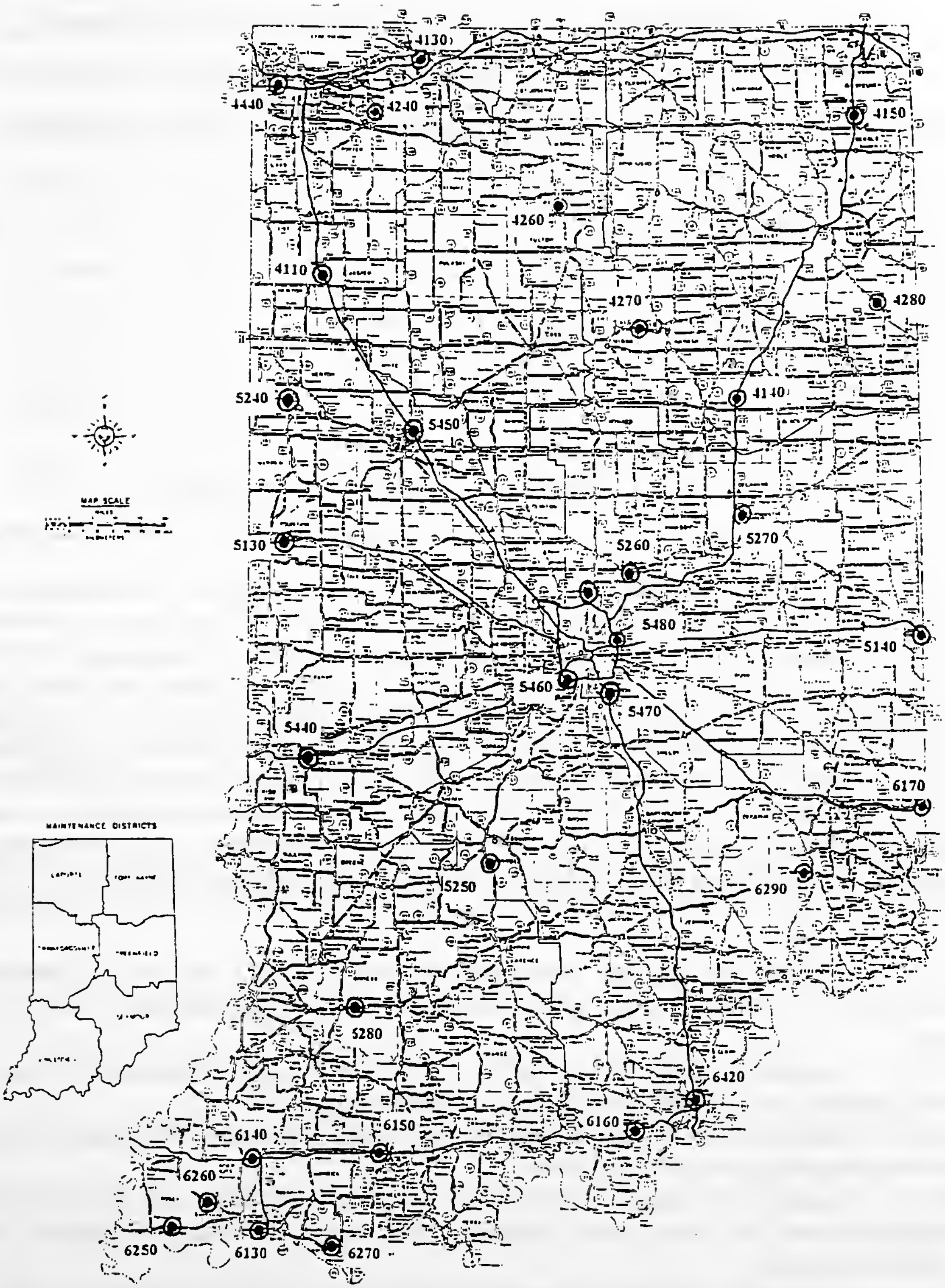


Figure C-3.3
Map of the State of Indiana showing locations of existing truck-weighing ATRs

Table C-3.4 Weights attached to various factors for distribution of additional truck weight ATRs

Class / Factor	Interstates	Other Principal Arterials	Minor Arterials	Collectors
1. Location on NHS segment (wf1)	15%	15%	20%	20%
2. Proximity to state border (wf2)	40%	20%	10%	5%
3. Location on HPMS sample section (wf3)	0%	0%	0%	0%
4. Geographical distribution (wf4)	30%	35%	40%	40%
5. Possibility of upgrading existing equipment (wf5)	15%	30%	30%	35%
TOTAL	100%	100%	100%	100%

As has already been discussed in section C (g).2.1 of this document, the locations of additional ATR sites in each group, will be selected from several potential sites. For this count type (truck weight), only one group is being considered, i.e., Interstates. Potential sites will include existing sites used for other count programs, suitable "old" sites, and sites chosen based on engineering judgment. Points will be allocated to each site depending upon whether (or how well) each of theses sites meet a given set of factors such as location of the potential site on the NHS. To each factor point thus allocated to each potential site a weight will be applied to reflect the relative importance of that factor. Finally, all weighted points for each potential will be summed up, and the potential site with the highest sum is the first choice candidate for an additional ATR site.

C-3.4.1 NHS locations: As has been indicated on Table C-2.4.1(a), all the potential locations lie on the National Highway System, and are therefore allocated a point of 1 each.

C-3.4.1 Proximity to border: Only 4 of the 12 potential sites are considered as being in close proximity to the border, and are thus assigned points of 1.

C-3.4.1 Location on the HPMS: all the potential locations lie on an HPMS segment, and are therefore allocated a point of 1 each.

C-3.4.1 Possibility of upgrading: Of the 12 sites under consideration, 7 have existing equipment used for other count programs, and these sites may be upgraded to classification status.

C-3.4.1 Geographical distribution: The minimum distances, in miles, of potential truck-weighing ATR locations from existing truck-weighing ATR sites, for Interstates, are as follows:

min[P(1)E(j)] = 10.35	min[P(11)E(j)] = 20.72	min[P(21)E(j)] = 1.48
min[P(2)E(j)] = 3.71	min[P12)E(j)] = 40.71	min[P(22)E(j)] = 11.15
min[P(3)E(j)] = 2.22	min[P13)E(j)] = 4.70	
min[P(4)E(j)] = 36.63	min[P14)E(j)] = 7.66	
min[P(5)E(j)] = 11.84	min[P(15)E(j)] = 2.16	
min[P(6)E(j)] = 12.58	min[P(16)E(j)] = 8.14	
min[P(7)E(j)] = 14.05	min[P(17)E(j)] = 3.70	
min[P(8)E(j)] = 5.18	min[P(18)E(j)] = 26.64	
min[P(9)E(j)] = 17.76	min[P(19)E(j)] = 9.69	
min[P(10)E(j)] = 2.20	min[P(20)E(j)] = 11.85	

The resulting choices on the basis of geographical distribution by network analysis are shown in the table below:

Table C-3.4.1
Choice ranking of potential locations on basis of geographical distribution only, for Interstates

Choice	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
Potential site	P12	P4	P18	P11	P9	P7	P20	P5	P6	P22	P1

Choice	12th	13th	14th	15th	16th	17th	18th	19th	20th	21st	22nd
Potential site	P16	P14	P8	P2	P13	P17	P19	P3	P10	P15	P21

Table C-3.4.2
Example of engendered network changes at each step of network analysis
Group 1: Interstates

Step	Assignment of potential classification ATR P(k) to "existing classification ATR" category	New minimum distances
1.	P(12)	none
2.	P(4)	none
3.	P(18)	none
4.	P(11)	none
5.	P(9)	none
6.	P(7)	min[P(7)E(j)] = 11.83
7.	P(20)	none
8.	P(5)	none
9.	P(6)	none
10	P(22)	min[P(19)E(j)] = 2.98
11.	P(1)	none
12.	P(16)	none
13.	P(49)	none
14.	P(8)	none
15.	P(2)	none
16.	P(13)	none
17.	P(17)	none
18.	P(19)	none
19.	P(3)	none
20.	P(10)	none
21.	P(15)	none
22.	P(21)	none

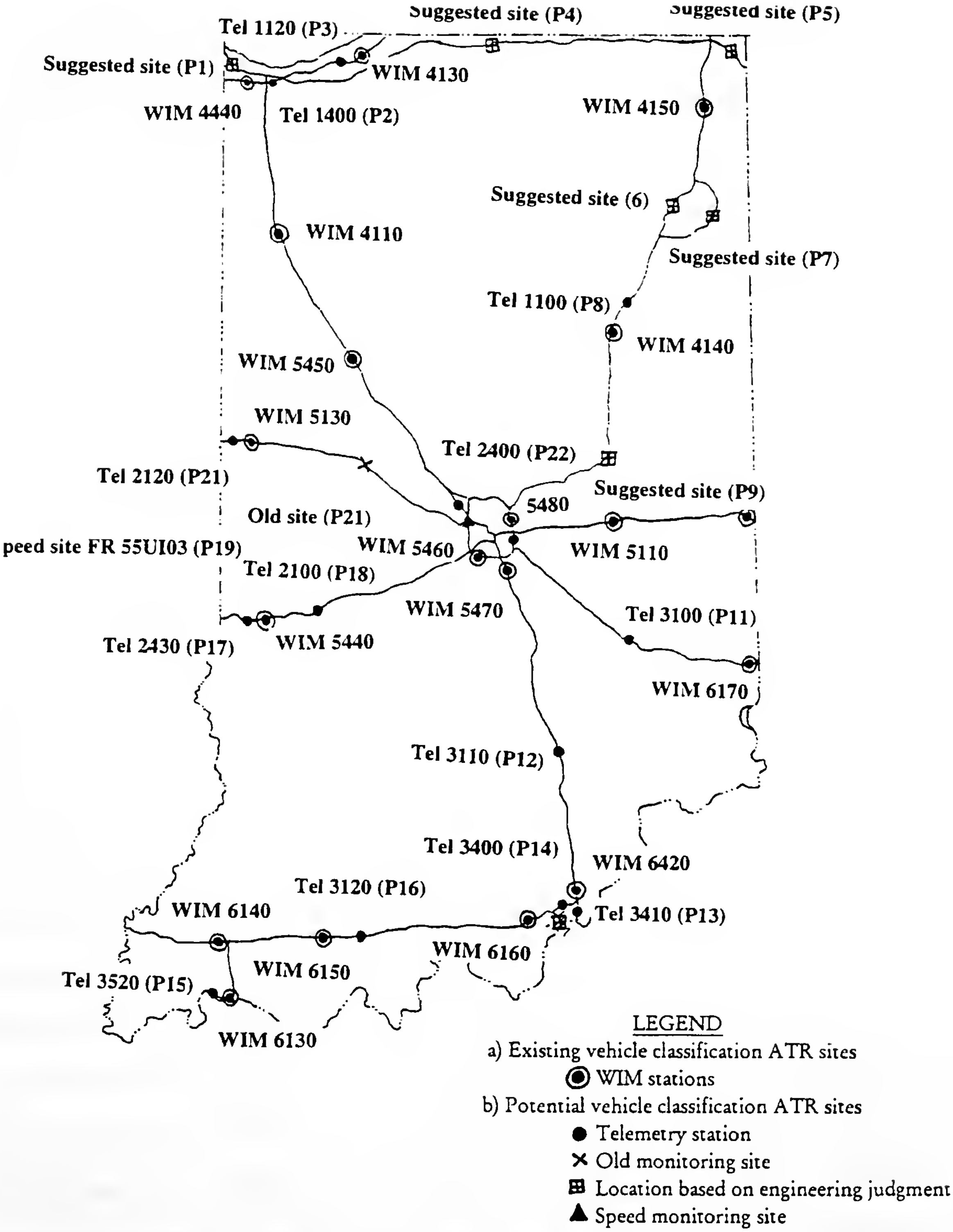


Figure C-3.4- Map of Interstate Roads in the State of Indiana showing locations of existing and potential truck weighing ATR (WIM) locations

Table C-3.4.3: Evaluation of potential locations for truck weight ATRs (WIMs)
Seasonal Factor Group1:Interstates, Part 1: Allocation of points to potential sites

Factor / Potential site	Location on NHS. (pf1)	Proximity to state border. (pf2)	Geographical location. (pf3)	Possibility of upgrading. (pf4)
P1: Suggested site on I-90 in East Chicago	1	1	0.50	0
P2: Telemetry 1400	1	1	0.32	1
P3: Telemetry 1120	1	1	0.14	1
P4: Suggested site on I-80/90 near South Bend	1	1	0.91	0
P5: Suggested site on I-80/90 near Angola	1	1	0.64	0
P6: Suggested site on I-69 in Fort Wayne	1	0	0.59	0
P7: Suggested site on I-469 in Fort Wayne	1	0	0.73	0
P8: Telemetry 1100	1	0	0.36	1
P9: Suggested site on I-69 near Muncie	1	0	0.77	0
P10: Telemetry 2420	1	0	0.09	1
P11: Telemetry 3100	1	0	0.82	1
P12: Telemetry 3110	1	0	1.00	1
P13: Telemetry 3410	1	1	0.28	1
P14: Telemetry 3400	1	1	0.41	1
P15: Telemetry 3520	1	1	0.05	1
P16: Telemetry 3120	1	0	0.45	1
P17: Telemetry 2430	1	1	0.23	1
P18: Telemetry 2100	1	0	0.86	1
P19: Speed site FR55UI03 on I-465	1	0	0.18	1
P20: Old site on I-74 near Crawfordsville	1	0	0.68	1
P21. Telemetry 2120	1	1	0	1
P.22 Telemetry 2400	1	0	0.54	1

Table C-3.4.4: Evaluation of potential locations for truck weighing ATRs (WIM)
Group 1: Interstates
Part 2: Application of weights to points, and ranking of potential sites

Factor / Potential site	Location on NHS (pf1*wf1)	Proximity to state border (pf2*wf2)	Geographical location (pf3*wf3)	Possibility of upgrading (pf4*wf4)	Total points	Rank
P1: Suggested site on I-90 in East Chicago	0.15	0.40	0.15	0	0.70	9
P2: Telemetry 1400	0.15	0.40	0.09	0.15	0.79	3
P3: Telemetry 1120	0.15	0.40	0.04	0.15	0.74	7
P4: Suggested site on I-80/90, South Bend	0.15	0.40	0.28	0	0.83	1
P5: Suggested site on I-80/90 near Angola	0.15	0.40	0.19	0	0.74	6
P6: Suggested site on I-69 in Fort Wayne	0.15	0	0.18	0	0.33	21
P7: Suggested site on I-469 in Fort Wayne	0.15	0	0.22	0	0.37	19
P8: Telemetry 1100	0.15	0	0.11	0.15	0.41	17
P9: Suggested site on I-69 near Muncie	0.15	0	0.23	0	0.38	17
P10: Telemetry 2420	0.15	0	0.03	0.15	0.33	22
P11: Telemetry 3100	0.15	0	0.24	0.15	0.54	13
P12: Telemetry 3110	0.15	0	0.30	0.15	0.60	11
P13: Telemetry 3410	0.15	0.40	0.08	0.15	0.78	4
P14: Telemetry 3400	0.15	0.40	0.12	0.15	0.82	2
P15: Telemetry 3520	0.15	0.40	0.02	0.15	0.72	8
P16: Telemetry 3120	0.15	0	0.14	0.15	0.44	16
P17: Telemetry 2430	0.15	0	0.07	0.15	0.77	5
P18: Telemetry 2100	0.15	0	0.26	0.15	0.56	12
P19: Speed site FR55UI03 on I-465	0.15	0	0.05	0.15	0.35	20
P20: Old site on I-74 near Crawfordsville	0.15	0	0.20	0.15	0.50	14
P21. Telemetry 2120	0.15	0.40	0	0.15	0.70	10
P.22 Telemetry 2400	0.15	0	0.16	0.15	0.46	15

Total points for potential site k, = SUM [pf_i * wf_i], for i= 1 to 5
where pf_i = points "earned" by potential site k with respect to factor i
and wf_i = weight attached to factor i (see Table C-3.4)
The first 3 sites are selected. A list of these sites and their locations on the map, are provided in the "conclusions" section of this document.

C-4 OVERALL CONCLUSIONS AND RECOMMENDATIONS

For traffic volume ATRs, INDOT may continue to use the current seasonal group list for annualization of short term counts, because this criterion was associated with the least variation of data units and the best values of precision within its groups. The use of this criterion does not call for any additional volume-counting ATR site beyond the current number of 92. In fact, a significant number of existing traffic volume ATR sites in most of the groups were found to be in excess of those needed. However, it is recommended that no site be discontinued unless equipment at that site has had persistent history of malfunctioning. That way the expense of maintaining sites with malfunctioning equipment can be avoided.

For vehicle classification ATRs, a large number of new sites were found to be needed for most criteria that were considered. Among the non-cluster criteria, Criterion G (which groups ATRs on the basis of regional and functional classes) was adjudged the best , because this criterion led to least variation and best values of precision (using weighted averages). Furthermore, the composition of this criterion was found to fit that from the cluster procedure in the most convincing manner, even though a perfect fit was not obtained (nor expected).

A grouping criterion based on functional classes only was found to best address the truck weight patterns in the state, as was revealed by the various analyses.

The best locations for vehicle classification and truck weight ATRs have been found from various perspectives, such as the need to concentrate on the National Highway System, the desire for geographical distribution, the preference for HPMS locations, tie-in to other existing count programs, and other factors. It is, however, important to note that the recommended locations are only a rough guide, and an INDOT field crew may shift the final installation site a few tens or hundreds of meters upstream or downstream in order to ensure that installation makes use of available power sources, and avoids areas of deteriorated pavement, poor geometrics, and other unsuitable areas.

Recommendations for the locations of additional classification and weight ATRs were "synchronized" in order to avoid duplication of resources and to take advantage of the nested capabilities of currently available monitoring equipment (truck weight ATRs can also carry out classification). Therefore, all potential sites considered for additional truck weighing ATR locations were taken from the final list of recommended locations for

additional classification ATRs. This resulted in the desired overlap of recommendations for locations for additional ATRs for both count types. For example, the suggested ATR location on Interstate 80/90 in South Bend was recommended for both classification and weight ATRs. For such locations, the higher equipment level i.e., truck weight ATRs, should be installed because truck weight ATR are capable of generating classification data as well. Tables C-4.1 and C-4.2 show the list of the recommended locations for additional classification and weight ATRs, respectively, while Table C-4.3 shows a summary of the recommendations. Maps showing the locations of existing ATR sites are shown in Figures C-4.1 to C-4.3, while recommended locations for the additional ATRs are provided as Figures C-4.4 to C-4.6.

For all three count types, the selected grouping criteria makes it possible for INDOT to adjust the results of short-term coverage counts to yield annualized statistics such as AADT for traffic volumes. Also, using these grouping criteria, the precision of data may be checked every year to monitor how well changing traffic patterns in future match these selected criteria. In any case, it is essential that a consistent criterion for each count type be adopted for use by the State.

Future work in this area includes repetition of this study for each several years worth of previous data that are reliable, and using projected values of traffic data for future years. Researchers in some states have found out that traffic patterns, if properly monitored, may not reveal significant changes from year to year. Other areas that merit future study are the estimation of errors inherent in data generated by ATR equipment as a basis for recommending an improved program for equipment calibration and checks on performance deviation. With the state's Traffic Monitoring System poised to take off, this is currently a critical area that needs to be addressed .

Furthermore, studies may be carried out to determine whether and how regression models can be effectively used as an alternative method for the estimation of seasonal adjustment factors for the State of Indiana. This would involve the use of dummy independent variables to represent the various attributes (functional class, area class, regional class, etc.), and using step-wise regression methods to arrive at the relationship (with seasonal factor Sf_i as its dependent variable) that has the best R^2 value. A study carried out for the State of Delaware by Faghri, Janaki and Parameswaran, using the regression analysis approach, yielded encouraging results.

Table C-4.1
(Complete list of selected locations additional vehicle classification ATRs)

1. Upgrading of existing Telemetry station 1120 on I-94 near Michigan City
2. Upgrading of Telemetry station 2400 on I-65 at Indianapolis
3. Upgrading of dedicated speed monitoring station NFUI03 on I-465 in Indianapolis
4. Upgrading of Telemetry station 1100 on I-69 near Marion town in Grant County
5. Establishment of new classification ATR station on I-80/90, near South Bend about 1 mile West of Elkhart County border.
6. Establishment of new classification ATR station on I-80/90, near Angola, about 5 miles West of Ohio State border.
7. Establishment of new classification ATR station on I-90 at East Chicago, about 5 miles East of Illinois State border.
8. Upgrading of Telemetry station 1400 on I-80/94 near Gary in Lake County
9. Establishment of new classification ATR station on I-469, in Fort Wayne, about 3 miles South of US Road 30E.
10. Establishment of new classification ATR station on I-69 near Muncie about 2 miles South of State Road 67.
11. Establishment of new classification ATR station on I-69 in Fort Wayne about 1.5 miles South of US Road 30W.
12. Establishment of new classification ATR station near Old Site #13, on I-74 near Crawfordsville.
13. Upgrading of existing Telemetry station 1520 on US-33 near Elkhart
14. Upgrading of existing Telemetry station 1200 on US-41 near Cedar Lake
15. Upgrading of existing Telemetry station 2510 on US-231 near Lafayette
16. Upgrading of existing Telemetry station 1430 on US-31 near South Bend
17. Upgrading of existing Telemetry station 2220 on US-24 near Wolcott
18. Upgrading of existing Telemetry station 1420 on US-33 near Fort Wayne
19. Upgrading of existing Telemetry station 1530 on US-30 near Warsaw
20. Upgrading of existing Telemetry station 1330 on SR-120 near Middlebury
21. Upgrading of existing dedicated speed monitoring station NF55RA08 on State Road 37 near Fort Wayne
22. Upgrading of existing Telemetry station 2340 on US-136 near Crawfordsville
23. Upgrading of existing Telemetry station 1320 on SR-124 near Bluffton
24. Upgrading of existing dedicated speed monitoring station NF55RA18 on SR-114 near Luther
25. Upgrading of existing Telemetry station 2530 on SR-67 near Muncie.
26. Upgrading of existing dedicated speed monitoring station NF55RA25 on US-31 near Peru
27. Upgrading of existing Telemetry station 2330 on SR-29 near Albany
28. Upgrading of existing Telemetry station 2230 on US-231 near Lafayette
29. Upgrading of existing Telemetry station 2210 on US-431 near Monticello
30. Upgrading of existing Telemetry station 1210 on US-30 near Valparaiso

31. Upgrading of existing Telemetry station 1220 on US-6 near New Paris
32. Upgrading of existing Telemetry station 1510 on SR-37, at Fort Wayne
33. Upgrading of existing Telemetry station 3100 on I-74 near Batesville
34. Upgrading of existing Telemetry station 3110 on I-65 near Seymour
35. Upgrading of existing Telemetry station 3400 on I-265 near New Albany
36. Upgrading of existing Telemetry station 3410 on I-65 near Clarksville
37. Upgrading of existing Telemetry station 2110 on I-70 near New Brazil
38. Upgrading of existing Telemetry station 3520 on I-164 near Evansville
39. Upgrading of existing Telemetry station 3120 on I-64 near Clarksville
40. Establishment of new classification ATR station on I-64 1 mile East of Illinois
41. Upgrading of existing Telemetry station 2420 on I-465 at Indianapolis
42. Establishment of new classification ATR station at suggested site on I-74, near Greenburg, Dekalb County.
43. Upgrading of existing dedicated speed monitoring station NF55RA26 on US-27 near Richmond
44. Upgrading of existing Telemetry station 3530 on SR-49 near Jasper
45. Upgrading of existing Telemetry station 3210 on US-50 near Aurora
46. Upgrading of existing dedicated speed monitoring station NF55UA27 on US-27 near Terra Haute
47. Upgrading of existing Telemetry station 3240 on US-41 near Staser
48. Upgrading of existing Telemetry station 2300 on SR-42 near Brazil
49. Upgrading of existing Telemetry station 3230 on SR-56 near Little York
50. Upgrading of existing Telemetry station 3510 on SR-66 near Evansville
51. Upgrading of existing Telemetry station 2920 on SR-45 near Bloomington
52. Upgrading of existing Telemetry station 3340 on US-41 near Princeton
53. Upgrading of existing Telemetry station 2520 on US-41 near Terre Haute
54. Upgrading of existing Telemetry station 3500 on SR-111 near Jeffersonville
55. Upgrading of existing dedicated speed monitoring station NF55RA03 on SR-62 near Jeffersonville
56. Upgrading of existing Telemetry station 2410 on SR-37 near Indianapolis

Table C-4.2

Complete list of selected locations additional truck weight ATRs

1. Establishment of new WIM site on I-80/90 near South Bend, near Elkhart Co. line
2. Upgrading of Telemetry station 3400 on I-265 at Jeffersonville, to WIM station
3. Upgrading of Telemetry station 1400 on I-80 near Portage, to WIM station

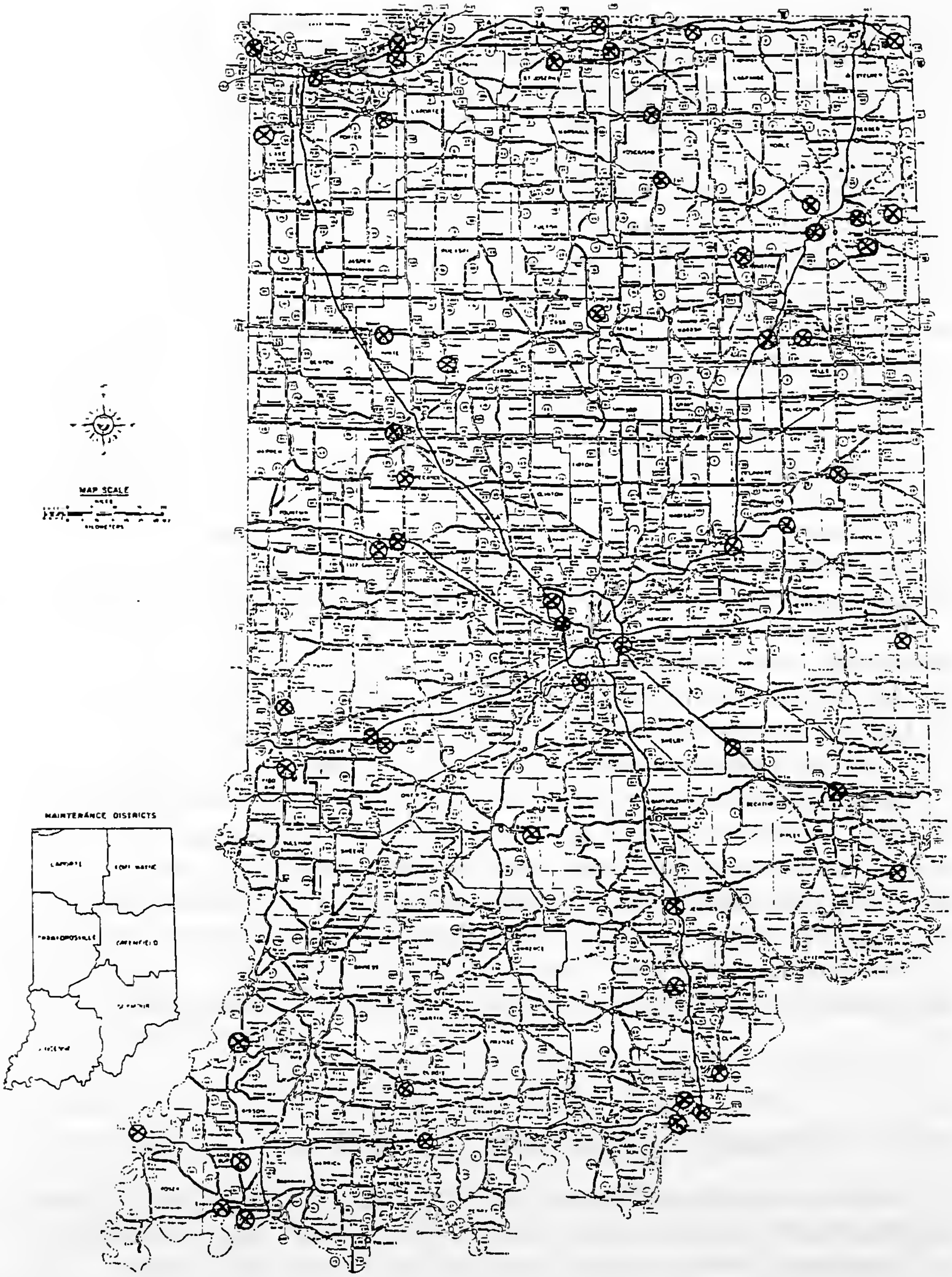


Figure C-4.3: Map of Indiana showing recommended locations
of additional classification ATRs

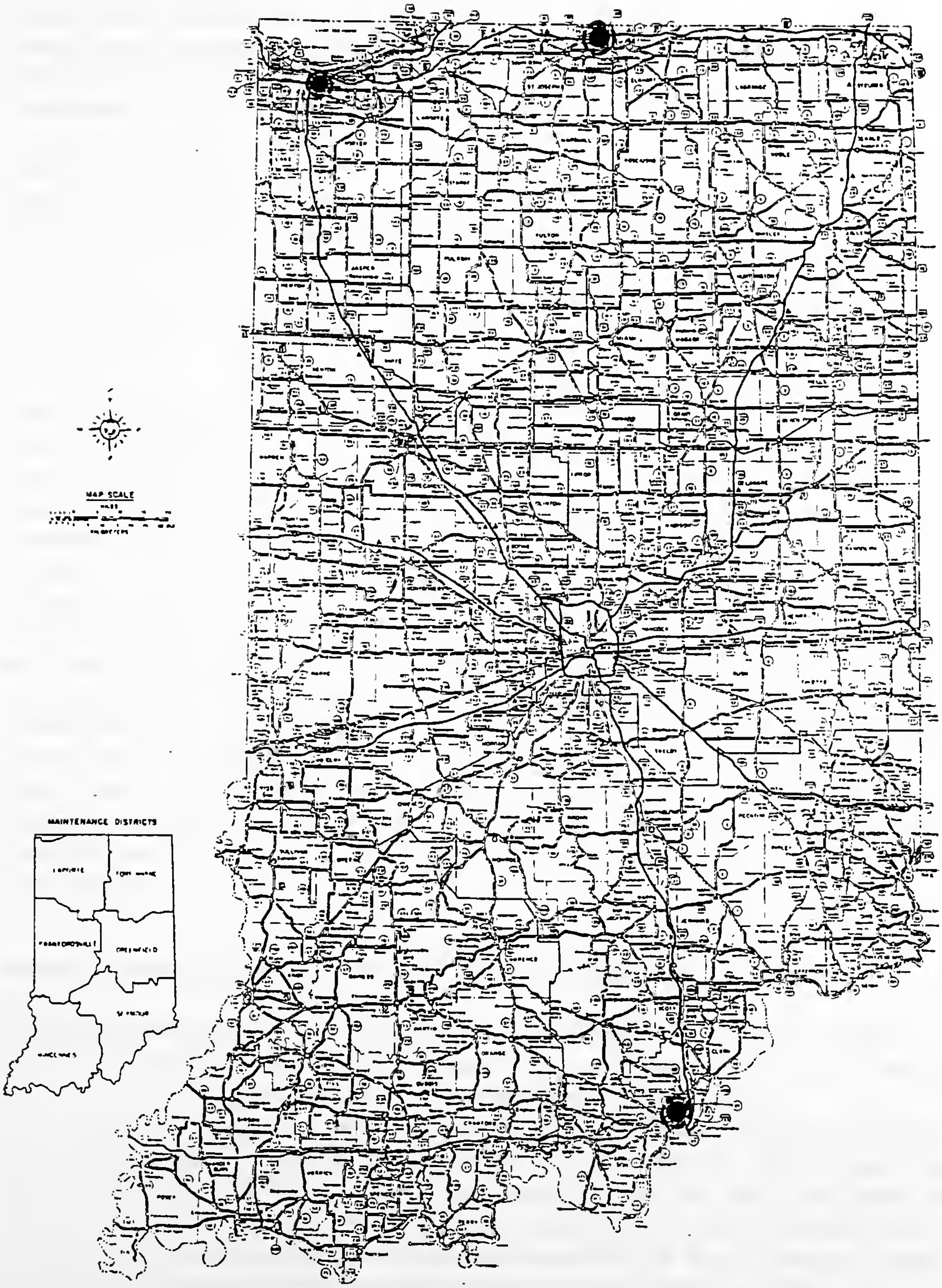


Figure C-4.5: Map of Indiana showing recommended locations of additional truck weighing ATRs (WIMs)

DRAFT TMS/H Data Action Plan **D1**
Short Term Coverage Counts I- Equipment Adequacy and Accuracy
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September 21, 1998.

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INDOT Work Plan Activity: Verification of Adequacy/Accuracy and Frequency of existing short term traffic counting equipment.

23 CFR Chapter 1, Subchapter F (Transportation and Infrastructure Management) Part 500 (Management and Monitoring Systems), Subpart H (Traffic Monitoring Systems For Highways) Section 500.807 (d) Federal Register, 1 December 1993, p. 63484 (Short Term Traffic Monitoring): " Count data for traffic volumes collected in the field shall be adjusted to reflect annual average conditions ... The duration and frequency of such monitoring shall comply to the data needs identified in Section 500.805 (a) of this Subpart."
Section 500.805 (a) of Subpart H states: "Each state shall develop, establish and implement, on a continuing basis, a Traffic Monitoring System for Highways to be used by Federal departments, agencies, states, local departments and public and private agencies [when] such data are used in support of the management systems ... [and when] the data are used in support of studies or systems which are the responsibilities of the US Department of Transportation."
Also, Section 500.805 (b) of Subpart H states: "The Traffic Monitoring System for Highways should be based on concepts described in the *[AASHTO] Guidelines for Traffic Data Programs* and the *Traffic Monitoring Guide,* and shall be consistent with the *HPMS Field* Manual."

INDOT'S SHORT-TERM TRAFFIC MONITORING PROGRAM

There are currently three categories of short-term counts being carried out by INDOT:

- Coverage (CFM) counts-This count program involves 48-hour monitoring for traffic volumes and vehicle classification.
- Coverage (HPMS) counts- This involves 48-hour monitoring of traffic volumes, vehicle classification, and truck weights. Truck weights are currently not a reporting requirement, and are thus only being monitored on an experimental level. This is a subset of the overall coverage counts.
- Special Request short-term counts- This is usually used for project-specific purposes, such as turning volume counts for signal design.

A. Coverage counts for the County Flow Maps (CFM) and other uses

The overall coverage count program was in existence before the HPMS, and has a very wide scope. Under this program, the Traffic Statistics Unit of INDOT conducts 48-hour counts on all state roads in each of the 92 counties in the state. This unit also counts non-state rural and non-state small urban HPMS road sections. With the exception of the truck weight aspect, the HPMS program can actually be considered a subset of the CFM coverage count program. A few non-state city streets and county roads are also counted as part of the CFM program. Currently, each county is counted on a rotating schedule of approximately four to five years.

The CFM program generates data that is used to support the HPMS in providing more accurate estimates of highway travel. The 48-hour count results are used to generate state-wide figures of AADT. To arrive at the estimated AADT, an axle correction factor is applied to convert the axle counts into vehicle counts. This count figure is then adjusted by multiplying it with a monthly seasonal variation factor (obtained from analysis of ATR data) to annualize the count into a 24-hour AADT estimate.

Other uses of the CFM program include preparation of traffic flow maps that are used by various state departments in highway administration, and generation of data for the management systems and other end users. The county flow maps are a collection of all AADT estimates for the entire state. Each map shows a county, the state roads contained in that county, and a number-letter code which has been assigned to various segments of the state roads. A listing, provided to the right of each map, shows the state road number, the number-letter code that corresponds to the map, the traffic volume estimated as AADT, and terminal points to which the estimated AADT applies.

Samples of County Flow Maps and County Vehicle Classification reports are attached as Appendices D1-I and D1-J respectively.

Coverage count locations are updated periodically in response to changing situations such as new traffic generators and new construction of roads, intersections, and bridges.

There is no indication of required count frequency for the CFM coverage count program in available INDOT or FHWA literature. Currently, the counts on the Indiana's Interstate system are being carried out on a two-year cycle, i.e., once every 2 years, traffic volumes on all interstate road segments are counted. However, from the recent editions of the County Flow Map book, it is obvious that most of the non-interstate roads are counted in a cycle of approximately 5 years. Significant efforts are being made by INDOT to reduce this cycle duration to about 3 years, in order to improve the "currentness" (and hence, usefulness) of the coverage count data.

Traffic data needs of the CFM coverage count program:

1. *Type of data required (count types):*
    - Traffic volumes (for estimation of AADT and DVMT)
    - Vehicle classification (Percentages of commercial vehicles)

2a. *Frequency (Option 1):*
- Interstate roads in all counties: 2-year cycle
- Non-Interstate roads:
    - Low-growth counties: 4 year count cycle
    - Average-growth counties: 3 year count cycle
    - High-growth counties: 2 year count cycle

2b. *Frequency (Option 2):*
- NHS roads in all counties: 2-year cycle
- Non-NHS roads
    - Low-growth counties: 4 year count cycle
    - Average-growth counties: 3 year count cycle
    - High-growth counties: 2 year count cycle

3. *Duration:* 48 hour minimum count duration

4. *Number of data collection sites*: In any county, selection of the locations of sites for counting are based on the following considerations:
    - Road sections between any two major intersections or interchanges
    - Road sections between a major intersection of a state road and a county or state border
    - Points on the non-state road system that pass over or under a state road
    - Contiguous segments for which traffic volumes differ by more than 10%, because of traffic generators, even if this would lead to further segmentation of a road section between major intersections

In order to concentrate its data collection activities on roads of higher priority, INDOT has maintained a monitoring cycle of 2-year length for Interstates. This cycle length for Interstates in all counties should be maintained, and possibly extended to all roads on the National Highway System (NHS). Also, it is desired that the coverage count activities should focus more closely on faster growing areas of the state. Therefore 2-, 3-, and 4-year cycle lengths may be used for monitoring non-Interstate or non-NHS roads in slow-growth, average-growth, and fast-growth areas respectively.

The option of concentrating traffic monitoring activities on NHS roads (Option 1) rather than only Interstates (Option 2), is recommended. This is because the signing of the National Highway System Designation Act in November 1995 took the nation beyond the Interstate era, setting in place a national road system that would be the focus of attention over the next few decades. Roads comprising the NHS were selected for their important contribution to the nation's economy, defense and mobility. The importance of the NHS

is reflected in the fact that the NHS comprises only 4 percent of the nation's road network in terms of mileage, yet it carries over 40 percent of all highway traffic and 75 percent of all heavy truck traffic. Also, 90 percent of the entire population of the U.S. lives within 8 km of an NHS route (*Public Roads*, Spring 1996 Edition). All Interstates are included in the NHS.

From a March 1997 publication by the United States Bureau of the Census, population trends in all counties in the state of Indiana have been obtained for the 1990 (census figures) and the 1996 (estimated) period, see Appendix D1-F. It is assumed that future growth of these counties would follow the same trends as that for the 1990-1996 period. Counties whose populations are expected to grow annually by <0.25% (slow-growth), 0.25-1.6% (average growth), and >1.6% (fast growth), have been identified. The source of population projections (i.e., US Bureau of the Census) was the same as that used by Clark and Fricker in their 1993 study titled *Updating Models to Forecast Traffic Volumes on Rural Segments of the State System.*

The analysis for the number of counts required (see Appendices) has been made using the count cycles indicated above, and by grouping all the 92 counties in Indiana in the three levels of expected population growth (see Appendix F). It has been assumed that population growth in a county would provide a fair indication of traffic growth. This analysis has been done for both options (i.e., NHS-focused and Interstate-focused).

B. Coverage counts for HPMS sections

The HPMS (Highway Performance Monitoring System) is described by the FHWA as a nationwide road inventory system that assesses system lengths, use, condition and operating characteristics of highway infrastructure. The operating characteristics include volumes, vehicle classifications and weights of highway traffic. On p. I-7 of the *HPMS Field Manual*, it is stated that the responsibilities of the state agencies include "... collection/assembly of timely reporting of high quality HPMS data in prescribed codes and formats." *The Traffic Monitoring Guide* of the FHWA, on page 2-4-3, states that "The HPMS element provides a minimum coverage framework of short-term counts for AVDT and AADT estimation ... The Guidelines of the HPMS (coverage) element recommend the use of 48-hour counts on the full sample of HPMS sections over a three-year cycle."

The traffic data needs of the HPMS and adequacy of the INDOT's coverage count program for HPMS reporting purposes have been addressed in Data Action Plan B.7 of this report. Therefore the rest of this data action plan focuses primarily on the adequacy of coverage counts for the County Flow Maps and other uses, and adequacy/accuracy of equipment used.

Special Needs Short-term Counts

The Roadway Management Division of INDOT often receives requests for traffic data at sites for which data generated by the existing coverage or continuous count programs cannot be extracted and reported, for a variety of reasons that may include the following:

- The location of the nearest ATR is too far from the site of interest to provide data that is adequately representative of travel at that site
- The most previous coverage count carried out at or sufficiently near the desired site is so outdated that it cannot represent current traffic trends at that site
- Data from a recent 48-hour coverage count are available, but the required duration of the requested special count is longer than the available duration.
- The count type required at that site is not made available by the existing continuous or coverage count programs, e.g., turning movements

The duration of these special request counts is usually short-term, and are used for preliminary engineering or project-specific purposes. According to the *AASHTO Guidelines for Traffic Data Programs*, p. 13, "Special request counts include rail crossing studies, bridge crossing studies, legislature requests, signal timing, signal warrants, capacity analysis...."

Special request counts are scheduled on an "as requested" basis. In most cases, the number (and other details such as count type and duration) of special count requests to be expected during the coming year is not known when the schedule for following year is being prepared. A reasonable contingency figure should therefore be assumed for such counts. For assessing the overall number of coverage counts required (see Appendices D1-D and D1-E), a figure of 1100 special request counts, based on previous records, has been assumed. For the Intermodal Management System (Data Action Plan B5), a total of 38 special counts on the state road system may be required every year. Therefore the total number of special counts assumed is 1138.

SHORT TERM COVERAGE COUNTS

1. Type of equipment required vs. type of equipment available

The type of equipment required depends on the type of data required, and the frequency and duration of the data collection activity. For all coverage counts in most states, portable equipment is used. Such portable equipment consists of simple pneumatic road tube equipment installed by mobile field crews. Each of such installations consists of pneumatic tubes installed at right angles to traffic lanes across the roadway with one end plugged. For vehicle classification activities, two tubes are used.

All of the equipment used for INDOT's short-term counts conforms to the configuration described above. A list of such equipment is provided in Appendix D1-C. Until 1988, the Archer Model counter/classifier equipment, manufactured by Golden River, was mainly used by INDOT to collect short-term data. However, since 1988, INDOT's short-term equipment inventory has been dominated by successive models of TrafiCOMP III counter/classifier models manufactured by PEEK Traffic Inc. According to INDOT, the performance of the PEEK equipment has been satisfactory.

In several states, there is a growing trend to give out some or all of the coverage counts to traffic count contractors. Currently there are two of such contractors that carry out special short-term traffic counts for INDOT. At the present time, it is not known whether this

short-term traffic counts for INDOT. At the present time, it is not known whether this trend is accompanied by shortfalls in quality control of data collection procedures. In any case, there is a need to strictly monitor the activities of such contractors, so that the overall quality of collected traffic data is not compromised.

2. Number of staff and amount of equipment required

2.1 Total number of counts needed per week

Approximate average number of volume and classification counts required per year, for option 2 (NHS) = 9940 (see Appendix D1-E):

Every year an effective period of 30 weeks are used for short-term counts. This is based on historical trends, and are due to the following assumptions:

- A typical workweek involves 37.5 hours
- Some working days are "lost" due to holidays, training sessions, meetings, inclement weather, vacations, sick days, special situations and the fact that setting up and removal of counters can only be done within regular working hours during a week with three consecutive working days.

Hence, average number of counts required per week = 9940/30 = 332

2.2 Total number of 1-man teams required:

INDOT's coverage counts are currently carried out several 1-man teams each equipped with a van, counters and road tubes.

From previous experience, the productivity of such a 1-man team = 26 counts per week

This figure is based on the following assumptions:

- 6-8 hours per week is used for transportation to site
- A maximum period of 45 minutes is used for setting up equipment, which includes a short period of manual observation to check whether the equipment is functioning correctly
- Count duration is 48 hours
- About 22 minutes are used for equipment removal

Therefore the number of 1-man teams needed to carry out an average of 332 counts in 1 week = 332/26 = 13

Each 1-man team requires a van and relevant accessories for the count activity.

2.3 Total number of counters needed

Equipment set up during a week are used only for that week. The same equipment is used for a different set of sites the following week.

If each 1-man team is to carry out 26 counts per week, then total number of counters required for each 1-man team = 26. This is a non-consumable item that is re-used the following week. However, it is suggested that at least three spare counters be available to each 1-man team to replace any counters that are later found to be defective.

Therefore, 29 counters are needed for each 1-man team.

For 13 teams, 377 i.e., 29*13, counters are needed

2.4 Total number of road tubes needed

From Coverage Count Field Report, 32% of all counts are classification counts.
Hence, 68% of all counts are volume counts.
Each volume count requires one tube, while classification counts require two tubes.
Then for each 1-man team,

> number of tubes needed for volume counts per week = 0.68 *26 *1 = 18,
> and number of tubes needed for classification counts per week = 0.32*26 *2 = 16
> total number of tubes needed per week = 44
>
> Road tubes are consumable items, and it is assumed road tubes can be used 5 times before replacement;
> then since 44 tubes can be re-used for 5 weeks, in 30 weeks 264 tubes are needed by a 1-man team.

For 13 one-man teams, 12* 264 tubes, or 3432 tubes are needed per year.
HPMS count sites are a subset of CFM count locations, hence no separate analysis is necessary to assess the adequacy of equipment for the HPMS count program.

The following table shows the required and existing resources:

Resource	Required number	Existing number	Remarks
Personnel	13	7	6 additional staff needed
Van and accessories	13	7	6 additional van and accessories needed
Counters	377	314 *(see Appendix D1-C)*	63 counters needed*1.
Road tubes	3432 standard lengths*2	see remarks	Consumable item. At least 3432 should be in stock for an entire year's operation*3.

*1: Instead of purchasing 63 new counters, only 43 may be purchased, and supplemented with 20 Numetrics HiSTAR NC-90A magnetic imaging equipment, for experimental use.
*2: A standard length is the average width of a 2-lane roadway
*3: Instead of ensuring that a stock of 3432 standard lengths of road tube are available, only 3422 standard lengths may be stocked for a years operation, and supplemented by 10 MITRON POPPS sensors of standard two-lane lengths, for experimental use.

3. Accuracy of short-term monitoring equipment

3.1 Possible sources of equipment error

3.1.1 Errors caused by traffic flow

According to the *AASHTO Guidelines for Traffic Data Programs*, on page 25, correctly functioning road tube counters that are placed on roads with traffic volumes near 5000 AADT, can be expected to have a machine error that is less than 10%. As traffic volume approaches 10,000 AADT on multi-lane roads, the error may exceed 10%. An explanation for the greater error associated with the latter case is the "masking" of some vehicles because other vehicles hit the road tube at the same time.

From experience, the magnitude of machine errors is expected to increase for tubes installed at pot-holed or severely rutted road sections. It is therefore necessary for INDOT's traffic data collection field crews to take this factor into consideration when selecting an exact location for short-term counts. At some locations the field crew is left with no choice because of widespread occurrence of such surface distress conditions on the road surface, especially for unpaved roads.

Vehicles changing lanes at the equipment locations also cause errors in recorded data.

It is recommended that:
- Careful quality control should be enforced for directional counts on multi-lane roads.
- Pot-holed and severely rutted sections (i.e., where rut depths exceed 2 cm) should, as much as possible, be avoided during site selection for the counts.
- Points where many lane-changing maneuvers are expected should be avoided
- Spot check tests that are currently carried out by INDOT field personnel after setting up their equipment at each site, should be continued.

3.1.2 Errors caused by speed of traffic

According to the *AASHTO Guidelines*, one source of error in both traffic counting equipment and vehicle classifiers is related to traffic speed. As speeds increase, road tube-based counters may miss the second axle of a tandem or tridem group of axles. This is attributed to the displacement of air in the road tube not allowing the air switch to normalize before the next axle impact. The Guidelines states that errors due to speed seem to be more prevalent in road tube counters than in other types of equipment.

3.1.3 Errors due to malfunctioning equipment

The *AASHTO Guidelines for Traffic Data Programs* indicate that machine errors exceeding +/- 10% for portable equipment is unacceptable for volume counts. The Guidelines further state that "vehicle classifiers should be accurate to 90% of all vehicles in the traffic stream". A sample estimation of machine error during calibration testing is provided in Appendix D1-A and D1-B for volume counts and vehicle classifications, respectively. If single pneumatic road tube counters are used, it must be noted that the results should be corrected by an axle adjustment factor, because such equipment record each axle.

3.2 Testing of short-term monitoring equipment

As suggested on page 22 of the *AASHTO Guidelines for Traffic Data Programs*, INDOT's testing program for short-term monitoring equipment should consist of calibration tests and performance deviation tests.

Performance deviation tests (spot-checks): Deviations in device performance are monitored regularly by the INDOT field technicians. Simple manual counts can be carried out to check equipment accuracy. This is done after setting up the equipment, prior to taking of the 48-hour measurements. Its duration may range from 5-20 minutes. According to INDOT's contact person for this data action plan, this test involves manual observation of an unspecified number of vehicles and comparison of this result with that recorded by the machine within the same time interval, to ensure that the machine is working properly. For new counters or road tubes, a maximum of 30 minutes may be used. These checks usually expose several sources of error (such as holes in road tubes) that may have escaped visual detection.

Such performance deviation test carried out by INDOT's field crew should be continued. The current practice of checking road tubes for physical signs of distress such as "Chinese fingers" even before equipment set-up should also be maintained. It is also recommended that the manufacturers be alerted to any persistent problems associated with the equipment.

Field personnel should be able to determine the source of any recording errors that may be discovered at this stage. i.e., whether such errors are due to malfunctioning equipment, or whether errors are being caused by the nature of traffic flow (e.g., frequent lane-changing maneuvers) or high traffic speeds.

INDOT's traffic counter technicians receive approximately ten weeks of supervised training at the beginning of their employment and consequently are relatively experienced before being allowed to work alone. According to the INDOT contact person for this data action plan, this training covers all aspects of traffic data collection, including safety, the manufacturer's recommendations, and precautions to ensure collection of accurate data.

INDOT's contact person further states that the main reference, "collectively retrieved" from the FHWA's *Traffic Monitoring Guide*, The *AASHTO Guidelines*, various INDOT memos, and experience earned by INDOT's personnel over a substantial period of time, is the "Manual for Traffic Counter Technician IIIs".

In some other states such as Idaho, the current practice is to carry out spot checks before the counter is used, to make sure it is working when it is set out, and again when it is retrieved.

Calibration tests: For each unit of equipment, a minimum of one test per year is recommended. From such a test, a benchmark for performance would be established, and would serve as a basis for comparing results of subsequent calibrations and spot check

tests. The testing exercise would make it possible for INDOT to monitor performance of a particular machine over a period of time, and also of several similar machines at a given point in time.

According to INDOT's contact person for this data action plan, all traffic counters and classifiers in INDOT are fully bench tested for operation and accuracy at least once a year under a service contract with the manufacturer. This is in line with calibration testing requirements spelt out in the *AASHTO Guidelines.*

Within the yearly interval between calibration testing activities by the manufacturers, INDOT may desire to carry out its own in-house calibration tests to confirm that a particular equipment is operating properly. With regard to calibration testing of volume-counting equipment, 100 vehicles or 15 minutes, whichever is reached first, may be selected as the criterion for the duration of testing. These limits may be slightly modified by the field supervisor depending on field conditions. Appendix D1-A shows the form for recording and analysis of results of volume-counting equipment testing.

For calibration testing of vehicle classification equipment, the number of vehicles to be monitored should be sufficiently large. Thirty vehicles is a recommended minimum. A vehicle that is erroneously classified into a class lower than its actual class is described as an under-classified vehicle, while one that is placed in a class higher than its actual class is described as having been over-classified. In both cases, the vehicles are described as mis-classified. Appendix D1-B(i) is the recommended form for testing vehicle classification equipment, while Appendix D1-B(ii) shows the suggested form for analyzing the results.

Road sections used for calibration tests should be "closed", i.e., without any branch roads. Preferably such roads should be at locations where traffic volumes are relatively low and can be safely controlled by the field crew.

During calibration testing, several equipment, instead of just one, may be installed on a particular road section. This way the overall time used for testing the equipment may be reduced and the results would provide a basis for comparing the relative performance of the equipment.

The MPOs in the State of Indiana have not indicated any efforts on their part to ensure that all equipment used is subjected to regular field performance deviation and calibration tests. It is obvious that the traffic data collection staff strengths of most MPOs are not enough to carry out this added activity. Nevertheless, INDOT should make use of its regular forums and workshops to educate the MPOs about the need for field-testing and how to carry out some of such activities with minimal staff.

The DOT of the State of New York uses a portable counter validation procedure in which several counters are set out adjacent to each other with road tubes attached to two "channels". The hourly count data obtained from each channel is entered on a spreadsheet

and the number of channels in each hour that exceed the average value by +/- 2% is computed. When hourly values are out of the range the data for the machine and channel number that are most out of line are blanked out and the spreadsheet is recalculated. If necessary, the process is repeated eliminating bad count data one machine and channel number at a time until the remaining count data falls within +/- 2% of the actual average.

The State of Idaho DOT has developed programs that facilitate checking of counters and classifiers. These programs called Genlog and Classlog, permit the performance and storage of manual counts and classifications on a laptop computer, and facilitate the checking of classification axle counts and sensor errors. The data from Genlog and Classlog are compared with data from the counter to determine the accuracy of the counter. These tests are carried out randomly throughout the year for a period of one to three hours.
A precision target set by Idaho DOT is that "95% of the time, portable traffic recording equipment must operate within 5%", i.e., out of every 100 measurements, 95 should fall within 5% of the true value. According to Idaho DOT, if a portable counter does not achieve the required precision, it is set aside for further investigation. In the state of New York, the objective is to ensure that "the deviations of traffic count measurements do not exceed 2%" of the true value, presumably 100% of the time.

Portable weigh-in-motion counts have been recently activated by INDOT. However, some states such as Idaho, New York and Pennsylvania currently have very active portable WIM programs, and these states have developed various procedures to calibrate their equipment. In the state of Idaho, portable WIM equipment is calibrated twice each year. The testing is done at a port-of-entry (i.e., on roads at state borders where permanent static-weight stations are located) so that the dynamic weights can be compared with the static weights from the port. Also in that state, portable classification devices are checked each year using video equipment twice a year. Another method used by the state of Idaho DOT to check portable classification devices is to set such equipment at ATR sites for 48 hours, after which volume and classification data collected by both equipment are compared.

In a paper titled *Classification Algorithms/Vehicle Classifier Accuracy* presented at NATDAC '95, authors Bruce Harvey & Glenn Champion describe the results of field tests of a number of common classification devices currently in use throughout the country. The objective of these tests was to determine the accuracy of vehicle counting devices, the adequacy of equipment to correctly sort vehicles into the 13 FHWA vehicle classes, and the accuracy of automatic measurement of overall vehicle length. The tests were also intended to help study the effects of vehicle and axle sensor technology on vehicle classification, and the effects of vehicle repetitions and weather on axle sensors. These tests were performed by the Georgia DOT and the Georgia Tech Research Institute, and sponsored by the FHWA. Ground truth data was collected using computer-assisted analysis of each vehicle recorded on video. Equipment tested included TrafiComp and GK-6000 by Peek Traffic, Inc., TEL-2CM by Mikros Systems, AVC-100 by PAT Equipment Corp., TT-2001 by Diamond Traffic Products, TC/C 530-4D/4P/4L by

International Road Dynamics, Marksman 660 by Golden River Traffic, MSC-3000DCP by Mitron Systems, and Delta II by TimeMark Inc. The overall results and conclusions for this study include:

- The rate of failure of flexible piezoelectric axle sensors was much higher than that of rigid sensors.
- Performance of the piezoelectric axle sensors was the key factor in the overall classification accuracy of the devices tested. Even slight rutting in the lane caused significant problems in installation and operation of most axle sensors.
- All the classifiers required some adjustment after installation: some even required dis-assembly of the cases to adjust internal elements. None were turnkey devices.
- Classification errors were most common between Classes 2 (passenger cars) and Class 3 (pickups and minivans).
- The most accurately classified vehicle was the tractor trailer (Class 9), probably due to heavy axle loadings and unique axle configuration.

Alternative technology for short-term coverage counts at problematic count locations.

1. *Improved sensors to replace road tubes*: The use of tape switches instead of road tubes is recommended, especially in areas of fast-moving traffic. Tape switches provide better results under such traffic conditions. One problem switch tape-switch sensors, however, is that it is difficult to keep them fastened to the road surface, especially in wet weather. A new sensor called POPPS (Portable Over-Pavement Polymer Sensor), manufactured by MITRON Systems Corporation of Columbia, MD, shows much promise in overcoming this limitation. This equipment is re-usable and can work with any traffic counter that accepts piezoelectric or contact closure style inputs. It is capable of being fastened to the road surface using special screws, and does therefore not require a dry surface for adhesion. A universal adapter that comes with this equipment enables POPPS to work with other manufacturer's traffic recording units. Each adapter will support up to two POPPS.

The price of the POPPS sensor and its accessories are as follows:

Single-lane sensor with 25 ft. Lead-in Cable - $299.00
Two-lane sensor with 25 ft. Lead-in Cable - $399.00
POPPS Universal Adapter - $399.00

2. *Magnetic imaging units to replace both road tubes and recording units (Hi-Star NC-90A Magnetic Classifier, by Numetrics, Uniontown, PA)*

The Hi-Star NC-90A is described by its manufacturer as "the ultimate, complete, self-contained traffic classifier/analyzer." This equipment works on the principle of vehicle magnetic imaging with presence. Powered by re-chargeable Ni-Cad batteries, and housed in an impact resistant die-cast aluminum case, the NC-90A is capable of providing traffic data for short-term periods under heavy traffic conditions with little or no delay to traffic, danger to field crew, inconvenience to motorists, and damage to the pavement. It is installed on the road surface by placing a metal protective cover over it and fastening the

cover to the roadway using nails driven by a nail gun. No physical contact is necessary to collect accurate data. And the counters are normally installed in the center of the traffic lanes so that vehicles pass over the counter.

After the desired period of monitoring, the protective cover and the equipment are easily retrieved from the road surface using a small pry bar. The NC-90A is designed for three modes of operation: the Verify mode for provision of real time traffic analysis; the Frame mode which files each vehicle's speed and length into a particular pre-defined speed and length bin; and the Sequential mode which is used for in-depth studies that track vehicle movement in seconds, along with the vehicle's speed and length. Therefore, this equipment is capable of vehicle classification based on length. Hi-Star equipment may be programmed for data collection from any DOS compatible laptop, notebook, or PC.

The Numetrics magnetic imaging equipment are known too be somewhat vulnerable to interference from extraneous magnetic fields generated by electric power stations and other similar sources of magnetic fields. Site selection for installing such equipment therefore needs to be carried out with caution. Many agencies, including MPOs in the State of Indiana, have rated the general performance of this equipment as satisfactory.

The price of a Hi-Star Volume Counter/Classifier, from a product catalogue, is $975. This includes a battery charger. Also, the price of the accompanying portable data management software, HDM-90, is $950. The Hi-Star portable 486 Laptop Computer is priced at $2,995, while the mounting straps and protective cover cost $60 and $175 respectively.

APPENDIX D1-A

Indiana Department of Transportation
Traffic Statistics Division

Calibration tests for short-term traffic volume counting equipment

Equipment ID #: Field Technicians:
Equipment type, age and condition: Weather
Date:
Test location: Time started: Time ended:

Duration of count interval	Machine Count	Actual Count (Manual, video, etc.)	Absolute Error	Percentage Error	Remarks
	a	*b*	*a-b*	*100*(a-b)/b*	

Comments: This form shows the desired situation, and may be used if there are enough staff to carry out this activity.

APPENDIX D1-B(i)

Indiana Department of Transportation
Traffic Statistics Division
Calibration tests for short-term vehicle classification equipment
Part 1: Field form

Equipment ID #: Field Technicians:
Equipment type, age and condition: Weather:
Date:
Test location: Time started: Time ended:

Vehicle	Machine classification	Actual classification (Manual, video, etc.)	Remarks
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			

Comments: This form shows the desired situation, and may be used if there are enough staff to carry out this activity.

APPENDIX D1-B(ii)

Indiana Department of Transportation
Traffic Statistics Division
Calibration tests for short-term vehicle classification equipment
Part 2: Form for data analysis

Equipment ID #:
Equipment type, age and condition:

Test location:

Field Technicians:
Weather:
Date:
Time started: Time ended:

Class	Actual number of vehicles in class	Number of vehicles under-classified	% of vehicles under-classified	Number of vehicles over-classified	% of vehicles over-classified	% of vehicles mis-classified
	a	*b*	*c=100*(b/a)*	*d*	*e=100*(d/a)*	*f = c + e*
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						

Remarks: Comments: This form shows the desired situation, and may be used if there are enough staff to carry out this activity.

APPENDIX D1-C

Existing equipment for short-term coverage counts

Manufacturer	Model	Type	Quantity	Purchase date	Current condition	Usage
Peek Traffic	TrafiCOMP II Model 141	Counter/ classifier	34	1984	Fair	Stored
Peek Traffic	TrafiCOMP III Model 241-2RT	Counter/ classifier	60	1987/1988	Good *1	Weekly
Golden River*2	Archer Model 6400	Counter/ classifier	37	1988	Fair	Several times a year
Peek Traffic	TrafiCOMP III Model 241-2RT	Counter/ classifier	106	1989/1994	Fair	Weekly
Peek Traffic	TrafiCOMP III Model: 241-4RT-8A-8P-8L	Counter/ classifier	18	1992/1994	Good	Several times a year
Peek Traffic	TrafiCOMP III Model 241-EZ	Counter/ classifier	86	1995/1996	Good	Weekly

Total = 351
Effective total=314 (excluding Golden River equipment)

*1- Recently refurbished and upgraded to 241-EZ
*2- This equipment classifies vehicles by length, not by axle configuration. Also, the format of its print-outs are not as desired. Therefore, this equipment is not used for 48-hour counts.

APPENDIX D1-D.i

Determination of number of short-term counts required per year
(Option 1: Preference given to *Interstate* roads and higher-growth counties)

Count program \ Year	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	Counts in each category, see App. D1-Dii and D1-Diii.
1. Interstate Counts (IC)	IC		IC		IC		IC		IC = 1116
2. Special counts (s)	s	s	s	s	s	s	s	s	s = 1138
3.1 Coverage counts on **Interstate** Roads during Non-IC years (I) — *Batch 1*, *Batch 2*		I1		I2		I3		I4	I1= 188 I2=74 I3= 120 I4= 164
3.2(a) Coverage counts on non-Int. roads, **average-**growth counties (A) — *Batch 1*	A1			A1			A1		A1=3754: 1141 locs
Batch 2		A2			A2			A2	A2=3922: 1192locs
Batch 3			A3			A3			A3=3724: 1132locs
3.2(b) Coverage counts on Non-Int. roads, in **low-**growth counties (L) — *Batch 1*	L1				L1				L1=1050: 319 locs
Batch 2		L2				L2			L2=1112: 338 locs
Batch 3			L3				L3		L3=1082: 329 locs
Batch 4				L4				L4	L4=1013: 308locs
3.3(c) Coverage counts on Non-Int. roads in **high-**growth counties (H) — *Batch 1*	H1		H1		H1		H1		H1=2096:637 locs
Batch 2		H2		H2		H2		H2	H2=1671:508 locs
Total counts	* 9797	* 8481	* 9799	* 8214	* 9285	* 8283	* 9823	* 8382	
Add 5% for repeated counts*[1]									
Final Total	**10286**	**8904**	**10288**	**8624**	**9748**	**8696**	**10313**	**8800**	Yearly average = **9458**

*1: Repetition of counts is often necessary due to damage to recording equipment caused by snow plows, checks on anomalous results, etc.

APPENDIX D1-Dii: Distribution of Interstate segments by County

APPENDIX D1-Dii: DISTRIBUTION OF COUNTY FLOW MAP SEGMENTS, INTERSTATES AND NON-INTERSTATES

COUNTY	Interstate	Average	growth	counties	High growth counties		Low	Growth	Counties		Total for	Growth	COUNTY
	Segments	A1	A2	A3	H1	H2	L1	L2	L3	L4	County	Rate (%)	
Blackford	0	-							27		27	0.08	Blackford
Cass	0							109			109	0.16	Cass
Delaware	4								72		76	0.15	Delaware
Fayette	0									29	29	0.14	Fayette
Gibson	3									69	72	0.08	Gibson
Grant	4									81	85	-0.16	Grant
Jay	0								53		53	0.17	Jay
Knox	0						82				82	-0.09	Knox
Lake	32							184			216	0.15	Lake
Miami	0									50	50	-0.19	Miami
Ohio	0									19	19	0.01	Ohio
Perry	3									60	63	0.09	Perry
Pike	0								47		47	0.09	Pike
Randolph	0						62				62	0.23	Randolph
Vermillion	2							45			47	0.02	Vermillion
Vigo	5								82		87	0.04	Vigo
Wabash	0						76				76	-0.19	Wabash
Warren	0								48		48	0.02	Warren
Wayne	7						99				106	0.02	Wayne
Total of non-interstate segments for each batch of low growth counties						→	318	338	339	308			
Adams	0		83									0.85	Adams
Allen	20			91								0.55	Allen
Barthmew	4			72								1.25	Bartholomew
Benton	0			47								0.4	Benton
Carroll	0	49										0.74	Carroll
Clark	11		84									0.9	Clark
Clay	2		64									1.2	Clay
Clinton	2		84									1.02	Clinton
Crawford	3			43								1.08	Crawford
Daviess	0	45										0.74	Daviess
Decatur	4	28										1.03	Decatur
Dekalb	4		61									1.44	Dekalb
Dubois	2	83										1.13	Dubois
Elkhart	4		111									1.36	Elkhart
Fountain	4			60								0.37	Fountain
Fulton	0			52								1.22	Fulton
Greene	0	101										1.39	Greene
Henry	4	69										0.34	Henry
Howard	0		45									0.88	Howard
Huntington	4		80									0.75	Huntington
Jackson	0			63								1.21	Jackson
Jefferson	0			75								0.69	Jefferson
Kosciusko	0	83										1.16	Kosciusko
Lagrange	2	36										1.48	Lagrange
Laporte	6		116									0.4	Laporte
Lawrence	0	85										0.98	Lawrence
Madison	5		93									0.27	Madison
Marion	67		107									0.27	Marion
Marshall	0			78								1.18	Marshall
Martin	0	40										0.34	Martin
Monroe	0		51									1.1	Monroe
Montgomery	4			80								0.93	Montgomery
Newton	0			59								1.3	Newton
Noble	0	74										1.57	Noble
Orange	0			46								0.74	Orange
Parke	0		43									1	Parke
Posey	3	47										0.37	Posey
Pulaski	0		41									0.61	Pulaski
Ripley	2			69								1.57	Ripley
Rush	0			48								0.86	Rush
St. Joseph	4	112										0.72	St. Joseph
Scott	3		66									1.32	Scott
Shelby	9		40									1.09	Shelby
Spencer	3			83								0.5	Spencer
Starke	0	62										0.48	Starke
Sullivan	0		53									0.98	Sullivan
Switzerland	0			33								1.38	Switzerland
Tippecanoe	0	124										0.99	Tippecanoe
Tipton	0		29									0.35	Tipton
Union	0			24								0.88	Union
Vanderburg	9			45								0.27	Vanderburg
Wells	0	57										0.45	Wells
White	3	77										1.3	White
Whitley	0			85								1.33	Whitley
		1141	1192	1132	← Total of non-interstate segments for each batch of average growth counties								
Boone	13				64							1.88	Boone
Brown	4					28						1.68	Brown
Dearborn	8				70							2.75	Dearborn
Floyd	9					64						1.64	Floyd
Franklin	1					46						1.65	Franklin
Hamilton	4				74							5.93	Hamilton
Hancock	3					43						2.37	Hancock
Harrison	3				99							1.93	Harrison
Hendricks	8				71							3	Hendricks
Jasper	5					59						2.26	Jasper
Jennings	0				29							2.17	Jennings
Johnson	4				46							3.06	Johnson
Morgan	3				73							2.18	Morgan
Owen	0					36						2.77	Owen
Porter	7					110						1.74	Porter
Putnam	3				47							1.72	Putnam
Steuben	5					65						2.06	Steuben
Warrick	4				64							1.91	Warrick
Washington	0					57						2.09	Washington
					637	508	← Total of non-interstate segments for each batch of high growth counties						
	338	← Total for all interstates											

An average of 3.29 counts are carried out per segment

APPENDIX D1-D.iii

Details of calculations for numbers shown on figure in Appendix D1-Di.

Overall count plan:

- Counts on all Interstates once every 2 years, i.e. the biennial intensive 3-month Interstate count program
- During years of Interstate counts, no other specific counts on Interstates in counties for which regular coverage counts are being carried out in that year
- During years of non-Interstate counts, separate counts to be carried out on Interstates in counties for which regular coverage counts are being carried out in that year

1. Interstate counts:

Every 2 years, INDOT carries out counts on all Interstate sections, within a three-month period. This count activity is independent of the regular coverage counts.
Total number of Interstate count locations = 338 (see Appendix D1.Dii)
Average number of counts per location = 3.29
Total number of Interstate counts = 338 * 3.29 = 1116

1. *Special counts:*

From Coverage Count Field Report (1996) submitted to INDOT Central Office by Traffic Data Collection Supervisor, number of special counts = 1461 at 65 locations.
Therefore, number of special counts per location = 1461/65 = 22.47
Similarly, for 1995, number of special counts per location = 939/61 = 15.88 = 16
And for 1994, number of special counts per location = 861/38 = 23

Mean of the average counts per location = 20.3, approximately 20

Average number of special count locations = (65+61+38)/3 = 55
Therefore, average number of special counts per year = 55 * 20 = 1100
Number of counts for the Intermodal Management System = 38
Therefore, average total number of special counts per year = 1138

3. Coverage counts on Interstate roads in counties for which general coverage counts are being carried out during non-IC years (A non-IC year is one in which the intensive 3-month Interstate Counts are not carried out):

Number of Interstate segments by batch and by growth regime (See Appendix D1-Dii):

a) Interstates in batch 1 of average growth areas, I_{A1} = 4+2+4+2+3+4+5+3 = 27
b) Interstates in batch 2 of average growth areas, I_{A2}=11+2+2+4+4+4+6+5+67+3+9=117
c) Interstates in batch 3 of average growth areas, I_{A3} = 20+4+3+4+4+2+3+9 = 49
d) Interstates in batch 1 of low growth areas, I_{L1} = 7
e) Interstates in batch 2 of low growth areas, I_{L2} = 32+2= 34
f) Interstates in batch 3 of low growth areas, I_{L3} = 4+5= 9
g) Interstates in batch 4 of low growth areas, I_{L4} = 3+4+3= 10
h) Interstates in batch 1 of high growth areas, I_{H1} = 13+6+4+3+8+4+3+3+4= 48

i) Interstates in batch 2 of high growth areas, I_{H2} = 4+9+1+3+5+7+8= 37

I1 = Interstate counts for counties in batch A2 + Interstate counts for counties in batch L2 + Interstate counts for counties in batch H2 (See figure in Appendix D1-Di) = $I_{A2} + I_{L2} + I_{H2}$
= 117 + 34 + 37 = 188

I2 = Interstate counts for counties in batch A1 + Interstate counts for counties in batch L4 + Interstate counts for counties in batch H2 (See figure in Appendix D1-Di) = $I_{A1} + I_{L4} + I_{H2}$
= 27 + 10 + 37 = 74

I3 = Interstate counts for counties in batch A3 + Interstate counts for counties in batch L2 + Interstate counts for counties in batch H2 (See figure in Appendix D1-Di) = $I_{A3} + I_{L2} + I_{H2}$
= 49 + 34 + 37 = 120

I4 = Interstate counts for counties in batch A2 + Interstate counts for counties in batch L4 + Interstate counts for counties in batch H2 (See figure in Appendix D1-Di) = $I_{A2} + I_{L4} + I_{H2}$
= 117 + 10 + 37 = 164

APPENDIX D1-E.i

Determination of number of short-term counts required per year
(Option 2: Preference given to NHS roads and higher-growth counties)

Year / Count program		1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	Counts in each category, see App. D1.Eii and D2-Eiii.
1. NHS Counts (NHS-C)		NHS-C		NHS-C		NHS-C		NHS-C		NHS-C = 3774
2. Special counts (s)		s	s	s	s	s	s	s	s	s = 1138
3.1 Coverage counts on **NHS** roads (h)			NHS1		NHS2		NHS3		NHS4	NHS1= 361 NHS2= 354 NHS3= 399 NHS4= 311
3.2(a) Coverage counts on non-NHS roads, **average-** growth counties (A)	*Batch 1*	A1			A1			A1		A1=3231: 982locs
	Batch 2		A2			A2			A2	A2=3280: 997locs
	Batch 3			A3			A3			A3=3270: 994locs
3.2(b) Coverage counts on Non-NHS roads, in **low-** growth counties (L)	*Batch 1*	L1				L1				L1=826: 251 locs
	Batch 2		L2				L2			L2=888: 270 locs
	Batch 3			L3				L3		L3=865: 263 locs
	Batch 4				L4				L4	L4=875: 266locs
3.3(c) Coverage counts on Non-NHS roads in **high-** growth counties (H)	*Batch 1*	H1		H1		H1		H1		H1=1773:539 locs
	Batch 2		H2		H2		H2		H2	H2=1754:533 locs
Total counts		* 9962	* 8950	* 10040	* 8888	* 10011	* 8940	* 10001	* 8937	
Add 5% for repeated counts*[1]										
Final Total		**10459**	**9397**	**10541**	**9331**	**10511**	**9386**	**10500**	**9383**	Yearly average = **9940**

*1: Repetition of counts is often necessary due to damage to recording equipment caused by snow plows, checks on anomalous results, etc.

APPENDIX D1-Eii: Distribution of NHS segments by County

COUNTY	NHS Segments	Average A1	growth A2	counties A3	High growth counties H1	H2	Low L1	Growth L2	Counties L3	L4	Total for County	Growth Rate (%)	COUNTY
Blackford	0								27		27	0.08	Blackford
Cass	31							78			109	0.18	Cass
Delaware	27								49		78	0.15	Delaware
Fayette	0									29	29	0.14	Fayette
Gibson	10									35	72	0.08	Gibson
Grant	13									72	85	-0.16	Grant
Jay	14								39		53	0.17	Jay
Knox	16						64				82	-0.09	Knox
Lake	57							159			216	0.13	Lake
Miami	17									33	50	-0.19	Miami
Ohio	0									19	19	0.01	Ohio
Perry	3									80	83	0.09	Perry
Pike	9								47		56	0.09	Pike
Randolph	16						48				64	0.23	Randolph
Vermillon	14							33			47	0.02	Vermillon
Vigo	25								62		87	0.04	Vigo
Wabash	9						67				76	-0.10	Wabash
Warren	9								39		48	0.02	Warren
Wayne	34						72				106	0.02	Wayne
Total of non-NHS segments for each batch of low growth counties →							251	270	283	268			
Adams	16		45									0.85	Adams
Allen	72			39								0.55	Allen
Barth'mew	6			70								1.25	Bartholomew
Benton	8			41								0.4	Benton
Carroll	8	44										0.74	Carroll
Clark	11		84									0.9	Clark
Clay	2		54									1.2	Clay
Clinton	9			37								1.02	Clinton
Crawford	5			43								1.08	Crawford
Daviess	31	14										0.74	Daviess
Decatur	4	26										1.03	Decatur
Dekalb	4		61									1.44	Dekalb
Dubois	16	48										1.13	Dubois
Elkhart	24		91									1.36	Elkhart
Fountain	4			80								0.37	Fountain
Fulton	8			46								1.22	Fulton
Greene	0	101										1.39	Greene
Henry	16	57										0.34	Henry
Howard	23			22								0.68	Howard
Huntington	15		69									0.75	Huntington
Jackson	15			48								1.21	Jackson
Jefferson	0			75								0.69	Jefferson
Kosciusko	12	71										1.18	Kosciusko
Lagrange	2	38										1.48	Lagrange
Laporte	10		114									0.4	Laporte
Lawrence	24	61										0.98	Lawrence
Madison	5		93									0.27	Madison
Marion	72		102									0.27	Marion
Marshall	15			63								1.18	Marshall
Martin	23	17										0.24	Martin
Monroe	15		36									1.1	Monroe
Montgomery	10			74								0.93	Montgomery
Newton	20	39										1.3	Newton
Noble	9	65										1.57	Noble
Orange	0			45								0.74	Orange
Parke	0		43									1	Parke
Posey	15	35										0.37	Posey
Pulaski	0		41									0.61	Pulaski
Ripley	10			61								1.57	Ripley
Rush	0			48								0.86	Rush
St. Joe	27	69										0.72	St Joseph
Scott	3		55									1.32	Scott
Shelby	9		40									1.09	Shelby
Spencer	23			43								0.5	Spencer
Starke	3	48										0.48	Starke
Sullivan	10		43									0.98	Sullivan
Switzerland	0			33								1.38	Switzerland
Tippecanoe	19	110										0.99	Tippecanoe
Tipton	3		26									0.35	Tipton
Union	10			14								0.88	Union
Vanderburg	20			34								0.27	Vanderburg
Wells	0	57										0.45	Wells
White	18	62										1.3	White
Whitley	7			78								1.33	Whitley
		982	867	964	← Total of non-NHS segments for each batch of average growth counties								
Boone	13				84							1.68	Boone
Brown	5				17							1.68	Brown
Dearborn	18				38							2.75	Dearborn
Floyd	9					84						1.64	Floyd
Franklin	1					46						1.68	Franklin
Hamilton	16					82						3.93	Hamilton
Hancock	3					43						2.37	Hancock
Harrison	3				99							1.93	Harrison
Hendricks	6				71							3	Hendricks
Jasper	5					50						2.28	Jasper
Jennings	6				21							2.17	Jennings
Johnson	9				41							3.06	Johnson
Morgan	12				84							2.18	Morgan
Owen	0					38						2.77	Owen
Porter	16					101						1.74	Porter
Putnam	3				47							1.72	Putnam
Steuben	6					65						2.08	Steuben
Warrick	11				37							1.91	Warrick
Wash'ton	0					57						2.09	Washington
					856	833	← Total of non-NHS segments for each batch of high growth counties						
	1167	← Total for all NHS segments											

An average of 3.29 counts are carried out per segment

APPENDIX D1-E.iii

Details of calculations for numbers shown on figure in Appendix D1-Ei.

Overall Count Plan:

- Counts on all NHS roads once every 2 years, during a biennial intensive 3-month NHS roads Count Program (proposed as Option 2)
- During years of NHS counts, no other specific counts on NHS in counties for which regular coverage counts are being carried out in that year
- During years of non- NHS counts, separate counts to be carried out on NHS roads in counties for which regular coverage counts are being carried out in that year

1. NHS counts:

Every 2 years, INDOT could carry out counts on all NHS segments, within a period of 3-4 months. This count activity would replace the current biennial 3-month Interstate Counts, and like the Interstate counts, would be independent of the regular coverage counts.

Total number of NHS count locations = 1147 (see Appendix D1-Eii)
Average number of counts per location = 3.29
Total number of NHS counts = 1147 * 3.29 = 3774

2. Special counts:

From Coverage Count Field Report (1996) submitted to INDOT Central Office by Traffic Data Collection Supervisor, number of special counts = 1461 at 65 locations.
Therefore, number of special counts per location = 1461/65 = 22.47
Similarly, for 1995, number of special counts per location = 939/61 = 15.88 = 16
And for 1994, number of special counts per location = 861/38 = 23

Mean of the average counts per location = 20.3, approximately 20

Average number of special count locations = (65+61+38)/3 = 55
Therefore, average number of special counts per year = 55 * 20 = 1100
Number of counts for the Intermodal Management System (see DAP B5) = 38
Therefore, average total number of special counts per year = 1138

3. Coverage counts on NHS roads in counties for which general coverage counts are being carried out during non-NHS-Count years (A non- NHS-Count year is one in which the intensive 3-4month NHS-Counts are not carried out):

Number of NHS segments by batch and by growth regime (See Appendix D1-Dii):

a) NHS segments in batch 1 of average growth areas,

NHS_{A1} = 5+31+4+16+16+12+2+24+23+20+9+15+27+3+19+18 = 244

b) NHS segments in batch 2 of average growth areas,

NHS_{A2}=18+11+2+4+24+15+10+5+72+15+3+9+10+3 = 201

c) NHS segments batch 3 of average growth areas,
NHS_{A3} = 72+6+6+9+3+4+6+23+15+15+10+10+23+10+20+7= 239

d) NHS segments in batch 1 of low growth areas, NHS_{L1} = 18+16+9+34 = 77
e) NHS segments in batch 2 of low growth areas, NHS_{L2} = 31+57+14 = 102
f) NHS segments in batch 3 of low growth areas, NHS_{L3} = 27+14+9+25+9 = 84
g) NHS segments in batch 4 of low growth areas, NHS_{L4} = 19+13+17+3 = 52
h) NHS segments in batch 1 of high growth areas,
NHS_{H1} = 13+5+18+3+8+8+9+12+3+11 = 88
i) NHS segments in batch 2 of high growth areas,
NHS_{H2} = 9+16+3+5+16+8= 58

NHS1 = NHS counts for counties in batch A2 + NHS counts for counties in batch L2 + NHS counts for counties in batch H2 (See figure in Appendix D1-Di) = NHS_{A2} + NHS_{L2} + NHS_{H2}
= 201+102+58= 361

NHS2 = NHS counts for counties in batch A1 + NHS counts for counties In batch L4 + NHS counts for counties in batch H2 (See figure in Appendix D1-Di) = NHS_{A1} + NHS_{L4} + NHS_{H2}
= 244+52+58 = 354

NHS3 = NHS counts for counties in batch A3 + NHS counts for counties in batch L2 + NHS counts for counties in batch H2 (See figure in Appendix D1-Di) = NHS_{A3} + NHS_{L2} + NHS_{H2}
= 239+102+58= 399

NHS4 = NHS counts for counties in batch A2 + NHS counts for counties in batch L4 + NHS counts for counties in batch H2 (See figure in Appendix D1-Di) = NHS_{A2} + NHS_{L4} + NHS_{H2}
= 201+52+58 = 311

APPENDIX D1-F

Expected population trends in Indiana counties (source: *US Bureau of the Census, March 1997*)
Average growth rates indicated are based on 1990-1996 population estimates.

Low growth counties:
(Annual growth <0.25%)

Blackford (0.08%)	Jay (0.17%)	Pike (0.09%)
Cass (0.18%)	Knox (-0.09%)	Randolph (0.23%)
Delaware (0.15%)	Lake (0.15%)	Vermillion (0.02%)
Fayette (0.14%)	Miami (-1.9%)	Vigo (0.04%)
Gibson (0.08%)	Ohio (0.01%)	Wabash (-0.19%)
Grant (-0.16%)	Perry (0.09%)	Warren (0.02%)
		Wayne (0.02%)

Average growth counties:
(Annual growth 0.25%- 1.6%

Adams (0.85%)	Huntington (0.75%)	St. Joseph (0.72%)
Allen (0.55%)	Jackson (1.21%)	Scott (1.32%)
Bartholomew (1.25%)	Jefferson (0.69%)	Shelby (1.09%)
Benton (0.4%)	Kosciusko (1.18%)	Spencer(0.5%)
Carroll (0.74%)	Lagrange (1.48%)	Starke(0.48%)
Clark (0.90%)	Laporte (0.40%)	Sullivan (0.98%)
Clay (1.20%)	Lawrence (0.98%)	Switzerland (1.38%)
Clinton (1.02%)	Madison (0.27%)	Tippecanoe (0.99%)
Crawford (1.08%)	Marion (0.27%)	Tipton (0.35%)
Daviess (0.74%)	Marshall (1.18%)	Union(0.88%)
Decatur (1.03%)	Martin (0.34%)	Vanderburgh (0.27%)
Dekalb (1.44%)	Monroe (1.10%)	Wells (0.45%)
Dubois (1.13%)	Montgomery (0.93%)	White (1.3%)
Elkhart (1.36%)	Newton (1.30%)	Whitley (1.33%)
Fountain (0.37%)	Noble (1.57%)	
Fulton (1.22%)	Orange (0.74%)	
Green (1.39%)	Parke (1.00%)	
Henry (0.34%)	Posey (0.37%)	
Howard (0.68%)	Pulaski (0.61%)	
	Ripley (1.57%)	
	Rush (0.86%)	

High growth counties:
(Annual growth >1.6%

Boone (1.88%)	Hancock (2.37%)	Morgan (2.18%)	Washington (2.09%)
Brown (1.66%)	Harrison (1.93%)	Owen (2.77%)	
Dearborn (2.75%)	Hendricks (3.00%)	Porter (1.74%)	
Floyd (1.64%)	Jasper (2.28%)	Putnam (1.72%)	
Franklin (1.66%)	Jennings (2.17%)	Steuben (2.06%)	
Hamilton (5.93%)	Johnson (3.06%)	Warrick (1.91%)	

APPENDIX D1-G

Distribution of coverage count locations (Interstates and non-Interstates) in the various counties, 1989-1994. Each location represents a road segment. Source: *Traffic Flow Map Report 1995*

Adams 1991- 63 (Interstates- 0, Non-interstates- 63)
Allen 1993- 111 (Interstates- 20, Non-interstates- 91)
Bartholomew 1991- 76 (Interstates- 4, Non-interstates- 72)
Benton 1991- 47 (Interstates- 0, Non-interstates- 47)
Blackford 1992- 27 (Interstates- 0, Non-interstates- 27)
Boone 1991- 77 (Interstates- 13, Non-interstates- 64)
Brown1993- 32 (Interstates- 4, Non-interstates- 28)
Carroll 1991- 49 (Interstates- 0, Non-interstates- 49)
Cass 1991- 109 (Interstates- 0, Non-interstates- 109)
Clark 1994- 95 (Interstates- 11, Non-interstates- 84)
Clay 1990- 56 (Interstates- 2, Non-interstates- 54)
Clinton 1990- 66 (Interstates- 2, Non-interstates- 64)
Crawford 1990- 46 (Interstates- 3, Non-interstates- 43)
Daviess 1992- 45 (Interstates- 0, Non-interstates- 45)
Dearborn 1992- 76 (Interstates- 6, Non-interstates- 70)
Decatur1993- 32 (Interstates- 4, Non-interstates- 28)
Dekalb 1992- 65 (Interstates- 4, Non-interstates- 61)
Delaware 1991- 76 (Interstates- 4, Non-interstates- 72)
Dubois 1992- 64 (Interstates- 2, Non-interstates- 62)
Elkhart 1990- 115 (Interstates- 4, Non-interstates- 111)
Fayette 1989- 29 (Interstates- 0, Non-interstates- 29)
Floyd 1994- 73 (Interstates- 9, Non-interstates- 64)
Fountain 1992- 64 (Interstates- 4, Non-interstates- 60)
Franklin 1992- 47 (Interstates- 1, Non-interstates- 46)
Fulton 1989- 52 (Interstates- 0, Non-interstates- 52)
Gibson 1991- 72 (Interstates- 3, Non-interstates- 69)
Grant 1990- 85 (Interstates- 4, Non-interstates- 81)
Greene 1989- 101 (Interstates- 0, Non-interstates- 101)
Hamilton 1993- 78 (Interstates- 4, Non-interstates- 74)
Hancock 1989- 46 (Interstates- 3, Non-interstates- 43)
Harrison 1989- 102 (Interstates- 3, Non-interstates- 99)
Hendricks 1990- 79 (Interstates- 8, Non-interstates- 71)
Henry 1990- 73 (Interstates- 4, Non-interstates- 69)
Howard 1991- 45 (Interstates- 0, Non-interstates- 45)
Huntington 1992- 84 (Interstates- 4, Non-interstates- 80)
Jackson 1991- 63 (Interstates- 0, Non-interstates- 63)
Jasper 1993- 64 (Interstates- 5, Non-interstates- 59)
Jay 1991- 53 (Interstates- 0, Non-interstates- 53)
Jefferson 1993- 75 (Interstates- 0, Non-interstates- 75)
Jennings 1993- 29 (Interstates- 0, Non-interstates- 29)
Johnson 1992- 50 (Interstates- 4, Non-interstates- 46)

APPENDIX D1-G (cont'd)

Distribution of coverage count locations (Interstates and non-Interstates) in the various counties, 1989-1994. Source: *Traffic Flow Map Report 1995*

Knox 1993- 82 (Interstates- 0, Non-interstates- 82)
Kosciusko 1990- 83 (Interstates- 0, Non-interstates- 83)
Lagrange 1994- 38 (Interstates- 2, Non-interstates- 36)
Lake 1989- 216 (Interstates- 32, Non-interstates- 184)
Laporte 1991- 124 (Interstates- 6, Non-interstates- 118)
Lawrence 1992- 85 (Interstates- 0, Non-interstates- 85)
Madison 1990- 98 (Interstates- 5, Non-interstates- 93)
Marion 1992- 174 (Interstates- 67, Non-interstates- 107)
Marshall 1994- 78 (Interstates- 0, Non-interstates- 78)
Martin 1992- 40 (Interstates- 0, Non-interstates- 40)
Miami 1992- 50 (Interstates- 0, Non-interstates- 50)
Monroe 1990- 51 (Interstates- 0, Non-interstates- 51)
Montgomery 1989- 84 (Interstates- 4, Non-interstates- 80)
Morgan 1993- 76 (Interstates- 3, Non-interstates- 73)
Newton 1993- 59 (Interstates- 0, Non-interstates- 59)
Noble 1991- 74 (Interstates- 0, Non-interstates- 74)
Ohio 1992- 19 (Interstates- 0, Non-interstates- 19)
Orange 1991- 45 (Interstates- 0, Non-interstates- 45)
Owen 1993- 36 (Interstates- 0, Non-interstates- 36)
Parke 1994- 43 (Interstates- 0, Non-interstates- 43)
Perry 1993- 63 (Interstates- 3, Non-interstates- 60)
Pike 1993- 56 (Interstates- 0, Non-interstates- 56)
Porter 1994- 117 (Interstates- 7, Non-interstates- 110)
Posey 1994- 50 (Interstates- 3, Non-interstates- 47)
Pulaski 1994- 41 (Interstates- 0, Non-interstates- 41)
Putnam 1991- 50 (Interstates- 3, Non-interstates- 47)
Randolph 1989- 62 (Interstates- 0, Non-interstates- 62)
Ripley 1993- 71 (Interstates- 2, Non-interstates- 69)
Rush 1993- 48 (Interstates- 0, Non-interstates- 48)
St. Joseph 1990- 116 (Interstates- 4, Non-interstates- 112)
Scott 1991- 58 (Interstates- 3, Non-Intestates- 55)
Shelby 1989- 49 (Interstates- 9, Non-Interstates- 40)
Spencer 1991- 66 (Interstates- 3, Non-interstates- 63
Starke 1991- 51 (Interstates- 0, Non-interstates- 51)
Steuben 1992- 73 (Interstates- 8, Non-interstates- 65)
Sullivan 1991- 53 (Interstates- 0, Non-interstates- 53)
Switzerland 1992- 33 (Interstates- 0, Non-interstates- 33)

APPENDIX D1-G (cont'd)

Distribution of coverage count locations (Interstates and non-Interstates) in the various counties, 1989-1994. Source: *Traffic Flow Map Report 1995*

Tippecanoe 1994- 129 (Interstates- 5, Non-interstates- 124)
Tipton 1993- 29 (Interstates- 0, Non-interstates- 29)
Union 1993- 24 (Interstates- 0, Non-interstates- 24)
Vanderburgh 1991- 54 (Interstates- 9, Non-interstates- 45)
Vermillion 1993- 47 (Interstates- 2, Non-interstates- 45)
Vigo 1991- 87 (Interstates- 5, Non-interstates- 82)
Wabash 1989- 76 (Interstates- 0, Non-interstates- 76)
Warren 1993- 48 (Interstates- 0, Non-interstates- 48)
Warrick 1991- 68 (Interstates- 4, Non-interstates- 64)
Washington 1992- 57 (Interstates- 0, Non-interstates- 57)
Wayne 1990- 106 (Interstates- 7, Non-interstates- 99)
Wells 1992- 57 (Interstates- 0, Non-interstates- 57)
White 1993- 80 (Interstates- 3, Non-interstates- 77)
Whitley 1994- 85 (Interstates- 0, Non-interstates- 85)

APPENDIX D1-H

Distribution of coverage count locations (NHS and non-NHS) in the various counties, 1989-1994.
Source: *Traffic Flow Map Report 1995 and INDOT NHS submission Nov 1995*

Adams 1991- 63 (NHS- 18, Non-NHS- 45)
Allen 1993- 111 (NHS- 72, Non-NHS- 39)
Bartholomew 1991- 76 (NHS- 6, Non-NHS- 70)
Benton 1991- 47 (NHS- 6, Non-NHS- 41)
Blackford 1992- 27 (NHS- 0, Non-NHS- 27)
Boone 1991- 77 (NHS- 13, Non-NHS- 64)
Brown 1991- 22 (NHS- 5, Non-NHS- 17)
Carroll 1991- 49 (NHS- 5, Non-NHS- 44)
Cass 1991- 109 (NHS- 31, Non-NHS- 78)
Clark 1994- 95 (NHS- 11, Non-NHS- 84)
Clay 1990- 56 (NHS- 2, Non-NHS- 54)
Clinton 1990- 66 (NHS- 9, Non-NHS- 57)
Crawford 1990- 46 (NHS- 3, Non-NHS- 43)
Daviess 1992- 45 (NHS- 31, Non-NHS- 14)
Dearborn 1992- 76 (NHS- 18, Non-NHS- 58)
Decatur 1993- 32 (NHS- 4, Non-NHS- 28)
Dekalb 1992- 65 (NHS- 4, Non-NHS- 61)
Delaware 1991- 76 (NHS- 27, Non-NHS- 49)
Dubois 1992- 64 (NHS- 16, Non-NHS- 48)
Elkhart 1990- 115 (NHS- 24, Non-NHS- 91)
Fayette 1989- 29 (NHS- 0, Non-NHS- 29)
Floyd 1994- 73 (NHS- 9, Non-NHS- 64)
Fountain 1992- 64 (NHS- 4, Non-NHS- 60)
Franklin 1992- 47 (NHS- 1, Non-NHS- 46)
Fulton 1989- 52 (NHS- 6, Non-NHS- 46)
Gibson 1991- 72 (NHS- 19, Non-NHS- 53)
Grant 1990- 85 (NHS- 13, Non-NHS- 72)
Greene 1989- 101 (NHS- 0, Non-NHS- 101)
Hamilton 1993- 78 (NHS- 16, Non-NHS- 62)
Hancock 1989- 46 (NHS- 3, Non-NHS- 43)
Harrison 1989- 102 (NHS- 3, Non-NHS- 99)
Hendricks 1990- 79 (NHS- 8, Non-NHS- 71)
Henry 1990- 73 (NHS- 16, Non-NHS- 57)
Howard 1991- 45 (NHS- 23, Non-NHS- 22)
Huntington 1992- 84 (NHS- 15, Non-NHS- 69)
Jackson 1991- 63 (NHS- 15, Non-NHS- 48)
Jasper 1993- 64 (NHS- 5, Non-NHS- 59)
Jay 1991- 53 (NHS- 14, Non-NHS- 39)
Jefferson 1993- 75 (NHS- 0, Non-NHS- 75)
Jennings 1993- 29 (NHS- 8, Non-NHS- 21)
Johnson 1992- 50 (NHS- 9, Non-NHS- 41)

APPENDIX D1-H (cont'd)

Distribution of coverage count locations (NHS and non-NHS) in the various counties, 1989-1994.
Source: *Traffic Flow Map Report 1995 and INDOT NHS submission Nov 1995*

Knox 1993- 82 (NHS- 18, Non-NHS- 64)
Kosciusko 1990- 83 (NHS- 12, Non-NHS- 71)
Lagrange 1994- 38 (NHS- 2, Non-NHS- 36)
Lake 1989- 216 (NHS- 57, Non-NHS- 159)
Laporte 1991- 124 (NHS- 10, Non-NHS- 114)
Lawrence 1992- 85 (NHS- 24, Non-NHS- 61)
Madison 1990- 98 (NHS- 5, Non-NHS- 93)
Marion 1992- 174 (NHS- 72, Non-NHS- 102)
Marshall 1994- 78 (NHS- 15, Non-NHS- 63)
Martin 1992- 40 (NHS- 23, Non-NHS- 17)
Miami 1992- 50 (NHS- 17, Non-NHS- 33)
Monroe 1990- 51 (NHS- 15, Non-NHS- 36)
Montgomery 1989- 84 (NHS- 10, Non-NHS- 74)
Morgan 1993- 76 (NHS- 12, Non-NHS- 64)
Newton 1993- 59 (NHS- 20, Non-NHS- 39)
Noble 1991- 74 (NHS- 9, Non-NHS- 65)
Ohio 1992- 19 (NHS- 0, Non-NHS- 19)
Orange 1991- 45 (NHS- 0, Non-NHS- 45)
Owen 1993- 36 (NHS- 0, Non-NHS- 36)
Parke 1994- 43 (NHS- 0, Non-NHS- 43)
Perry 1993- 63 (NHS- 3, Non-NHS- 60)
Pike 1993- 56 (NHS- 9, Non-NHS- 47)
Porter 1994- 117 (NHS- 16, Non-NHS- 101)
Posey 1994- 50 (NHS- 15, Non-NHS- 35)
Pulaski 1994- 41 (NHS- 0, Non-NHS- 41)
Putnam 1991- 50 (NHS- 3, Non-NHS- 47)
Randolph 1989- 62 (NHS- 16, Non-NHS- 48)
Ripley 1993- 71 (NHS- 10, Non-NHS- 61)
Rush 1993- 48 (NHS- 0, Non-NHS- 48)
St. Joseph 1990- 116 (NHS- 27, Non-NHS- 89)
Scott 1991- 58 (NHS- 3, Non-NHS- 55)
Shelby 1989- 49 (NHS- 9, Non-NHS- 40)
Spencer 1991- 66 (NHS- 23, Non-NHS- 43)
Starke 1991- 51 (NHS- 3, Non-NHS- 48)
Steuben 1992- 73 (NHS- 8, Non-NHS- 65)
Sullivan 1991- 53 (NHS- 10, Non-NHS- 43)
Switzerland 1992- 33 (NHS- 0, Non-NHS- 33)

APPENDIX D1-H (cont'd)

Distribution of coverage count locations (NHS and non-NHS) in the various counties, 1989-1994.
Source: *Traffic Flow Map Report 1995 and INDOT NHS submission Nov 1995*

Tippecanoe 1994- 129 (NHS- 19, Non-NHS- 110)
Tipton 1993- 29 (NHS- 3, Non-NHS- 26)
Union 1993- 24 (NHS- 10, Non-NHS- 14)
Vanderburgh 1991- 54 (NHS- 20, Non-NHS- 34)
Vermillion 1993- 47 (NHS- 14, Non-NHS- 33)
Vigo 1991- 87 (NHS- 25, Non-NHS- 62)
Wabash 1989- 76 (NHS- 9, Non-NHS- 67)
Warren 1993- 48 (NHS- 9, Non-NHS- 39)
Warrick 1991- 68 (NHS- 11, Non-NHS- 57)
Washington 1992- 57 (NHS- 0, Non-NHS- 57)
Wayne 1990- 106 (NHS- 34, Non-NHS- 72)
Wells 1992- 57 (NHS- 0, Non-NHS- 57)
White 1993- 80 (NHS- 18, Non-NHS- 62)
Whitley 1994- 85 (NHS- 7, Non-NHS- 78)

DRAFT TMS/H Data Action Plan **D2**
Vehicle Classification Activities on the National Highway System
Samuel Labi and Jon D. Fricker
September 21, 1998.

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INDOT Work Plan Activity: *Verification of adequacy/accuracy and frequency of existing Vehicle Classification Activities on the National Highway System (VCA-NHS).*

23 CFR Chapter 1, Subchapter F (Transportation and Infrastructure Management), Part 500 (Management and Monitoring Systems), Subpart H (Traffic Monitoring System for Highways) Section 500.807 (d) Short term traffic monitoring, Subsection (2), *Federal Register*, 1 December 1993, p. 63484, states: "Vehicle Classification Activities on the National Highway System (NHS) shall be sufficient to assure that, on a cycle of no greater than three years, every major system segment ... will be monitored to provide information on [classification of trucks and vehicles] and total number of vehicles operating on an average day".

With the acceptance of the Interim Final Rule *(Federal Register*, 19 December 1996) numbering of the above-quoted sections has been changed as follows: Section 500.807(b) is now 500.204(b).

A. TRAFFIC DATA NEEDS

1. **Data types**: Vehicle classification
   Traffic volumes
2. **Frequency and duration**: Maximum 3-year length of count cycle
   Minimum 48-hour count duration
3. **Locations**: All "segments" of the National Highway System in the State of Indiana

On November 28, 1995, the National Highway System Designation Act was signed. This act designates almost 260,000 kilometers of nationwide interstate roads and other major highways as the National Highway System (NHS). This was a milestone piece of legislation that took the nation beyond the Interstate era, setting in place a national road system that would be the focus of attention over the next few decades. The act has provisions affecting funding and innovative financing of highway projects and motor carrier regulations. Roads comprising the NHS were selected for their important contribution to the nation's economy, defense and mobility. The NHS comprises only 4 percent of the nation's road network in terms of mileage, yet it carries over 40 percent of all highway traffic and 75 percent of all heavy truck traffic, and 90 percent of the entire population of the U.S. lives within 8 km of an NHS route (*Public Roads*, Spring 1996 Edition)

The *Federal Register,* on p. 63484 of its December 1993 edition, requires that traffic volumes and vehicle classification be monitored for all segments on the National Highway System. For this purpose, the *Federal Register* defines a segment as " [the road section] between interchanges or intersections of principal arterials of the NHS with other principal arterials of the NHS." These sections, according to the *Federal Register*, should be monitored to provide information on the numbers of single trailer combination trucks, multiple trailer combination trucks, two-axle four-tire vehicles, buses, and the total number of vehicles operating on an average day.

For the purposes of this study, a "major intersection" is defined as the point where any two NHS roads cross each other, or where an NHS road meets a state boundary.

The *Federal Register* goes on to state that, if it is determined that two or more contiguous major system segments have both similar traffic volumes and distributions of the vehicle types identified above, a single monitoring session will be sufficient to monitor these segments.

The *Federal Register* does not offer a defining criterion for 'similarity', but for this exercise, the INDOT definition of similar segments as "contiguous road sections for which traffic volumes are within 10 percent of each other" (i.e., if the difference divided by the average is less than or equal to 0.10) will be used for this study. However, in line with INDOT procedures, such 'similar' segments will not be merged if they meet at a major intersection. Hence the latter criterion i.e., "major intersection", overrides the former, i.e., "volume similarity."

On the basis of the latter criterion it appears that none of the NHS segments needs to be merged on the basis of similarity of traffic volumes, since all such segments terminate at points considered "major intersections".

B. INFORMATION ABOUT THE EXISTING SITUATION

The 2807-mile National Highway System network in the State of Indiana consists of the Eisenhower Interstate System, Congressional High Priority Routes, STRAHNET Routes and Major Connectors, and other roads selected for their strategic importance to the nation. The NHS network in the State of Indiana (submitted by FWHA to INDOT on November 13, 1995) is provided as Appendix D2-A.

In a memo accompanying this submission, it was stated that the following changes had been made but were not yet reflected on the map:

Terre Haute Urbanized Area Map -SR 641 should be dashed all the way south to US 41.
Fort Wayne Urbanized Area Map - SR 469 should read I 469 and the line should be completely solid now. Also, SR 1 should read Baer Field Thruway.
Elkhart-Goshen Urbanized Area Map - SR 17 should read CR 17.

Chicago Urbanized Area Map - Burns International Harbor should be shown as an Indiana port.
South Bend - Mishawaka Urbanized Area Map - SR 331 should read Capital Avenue.
Louisville Urbanized Area Map - SR 62 should be dropped from the NHS in Indiana. Also, Clark Maritime Center should be shown.

The memo further stated that "these maps reflect the final and approved system, even though they say 'proposed' ".
In Appendix D2-B, the NHS map has been modified to reflect these changes. This sheet also shows the entire system, in both urban and non-urban areas of the state, on a single map.

Traffic data for the VCA-NHS is currently obtained from short term classification coverage counts at several coverage count sites, and at permanently-installed continuous ATR sites located at various points on the NHS network.

The ATR equipment on the NHS, which are at 28 weigh-in-motion (WIM) and 24 telemetry stations, are part of a greater number of state-wide ATR sites that were originally set up for the Long Term Pavement Performance Program (LTPP) and the Continuous Count element of the state's traffic monitoring program. ATR equipment collect data continuously throughout the year. Currently, data on vehicle classification and traffic volumes can be obtained at the WIM sites, but the telemetry sites currently generate only data on traffic volumes. Therefore, the only ATRs in the state that currently carry out vehicle classification are the WIM equipment.

As part of the state's Coverage Count element, short-term counts for vehicle classification are carried out at coverage count sections, some of which fall on the NHS. The duration (48 hours) of these counts are in accordance with the requirements of VCA-NHS.

Appendix D2(e) shows the NHS segments, while vehicle-classifying ATR sites and vehicle-classification coverage count sections that lie on the NHS network are provided as Appendix D2(f) to (h).

C. EVALUATION OF THE EXISTING SITUATION AND RECOMMENDATIONS

The goal of this work activity is to ensure that, for every segment on the National Highway System, vehicle classification and volume-counting are being carried out, either by an existing ATR site or coverage count section on that segment, or by a proposed special count for NHS segments that do not have such facilities.

This is in line with the philosophy of "holism and parsimony" espoused by the FHWA, which on p. 3-4-5 of the *Traffic Monitoring Guide,* recommends that separate counts for special needs not be carried out unless that need is not adequately covered by existing count programs.

The following steps were followed in determining the adequacy of the existing traffic data collection program for the VCA-NHS:

0) Divide the NHS network of roads into segments. A segment, as described in the *Federal Register* , is "the [road section]between interchanges or intersections of principal arterials of the NHS with other principal arterials of the NHS." A list of NHS segments is attached as Appendix D2(i).

1. Compare the existing distribution of vehicle-classifying ATR sites and vehicle classification coverage count sections, to the segmented NHS network.
If there is at least one vehicle-classifying ATR or coverage count site on every NHS road segment, then current traffic data collection system is adequate for vehicle classification activities on the NHS. If not, then the next step is followed.

2. Recommend that NHS segments that are not covered by the current vehicle-classifying ATR's or coverage count sites, be earmarked, under the Special Needs count element, for short-term monitoring using portable vehicle-classifying equipment or other technology, at the required frequency and duration.

Appendices D2(f) to (h) show the vehicle-classifying ATR sites that lie on the NHS network, and the vehicle-classification coverage counts on the NHS network during the following monitoring cycles: 1992-1994, 1993-1995, and 1994-1996 respectively. All vehicle classification activities on the National Highway System from 1992 to 1996 have been indicated on a single table, attached as Appendices D2(i).

By following the steps outlined above, it was found that the number of vehicle classification sites on NHS segments were as follows:

Three-Year Cycle	Number of NHS Segments counted	Percentage of entire NHS counted*1
1992-1994	83	51%
1993-1995	92	56%
1994-1996	89	54%

*1: Total number of NHS segments is 164.

Complete vehicle classification can be fulfilled for the National Highway System with implementation of the following recommendations:

a) With the implementation of the new count cycle for all NHS roads (see Data Action Plan D1), all NHS segments will be monitored for classification for at least 48 hours over

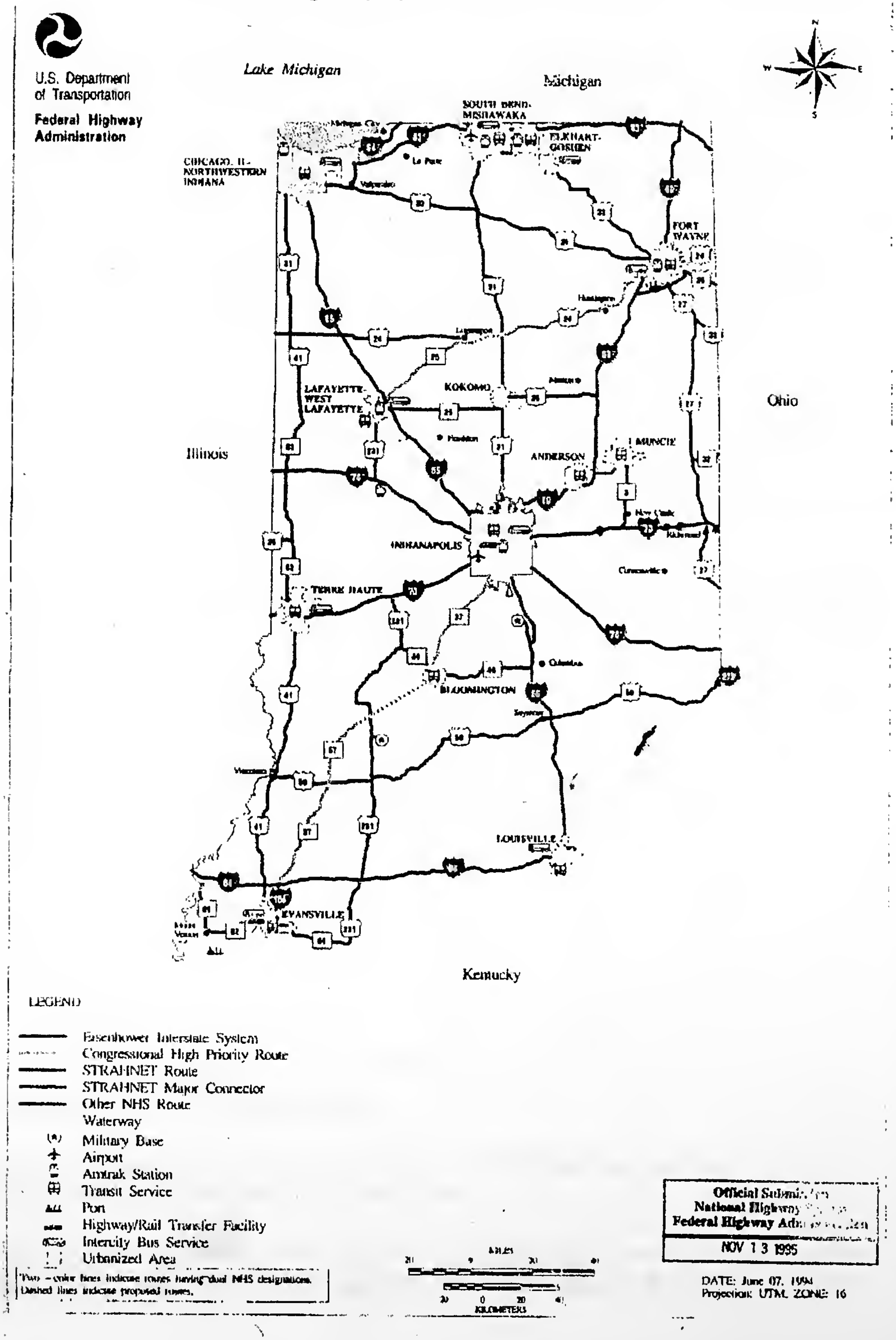
a minimum 3-year cycle length. The only exceptions are those NHS segments for which classification using traditional means is not possible, as explained in the next paragraph.

b) Classification counts are not carried out on some NHS segments because the nature of traffic flow on those segments precludes the performance of traditional monitoring activities. An example is Interstate 465, which has 10 NHS segments. Two of these segments have ATR equipment which generate classification data. Coverage counts cannot be carried out on the other 8 segments on the I-465 and other similar high volume roads because the very high traffic speeds on these roads not only pose a danger to the safety of field crew and may also cause recording errors in a manner described in section 3.1.2 on page 6 of Data Action Plan D1. Video-based monitoring systems or other non-intrusive technology could be used to obtain 48-hour classification data at such sites on a three year cycle to satisfy the VCA-NHS requirement for these sections. A detailed discussion of the resources needed for such a system is provided in Data Action Plan B3.

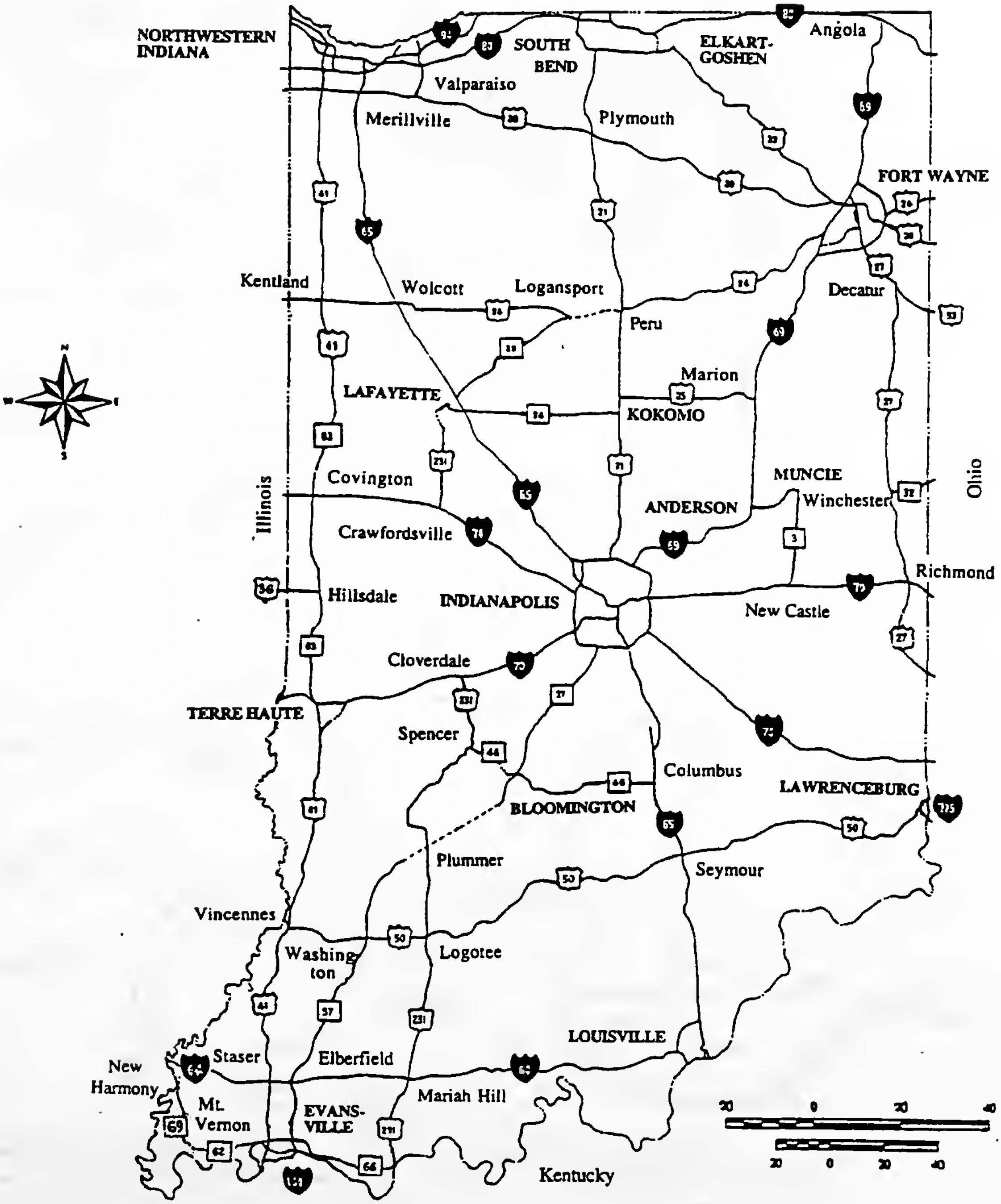
c) In Data Action Plan C, the upgrading of existing Telemetry sites has been recommended. Such an improvement would enable this equipment to collect data on vehicle classification. Hence NHS segments on which such equipment lie stand to benefit from this recommendation. For this reason, all Telemetry sites shown on the table in Appendix D2(i) have been marked with an asterisk.

Actually, vehicle classification on almost all NHS segments are presently being carried out by INDOT albeit over a cycle much longer than the specified minimum of 3 years, due to the fact that the current resources are not sufficient.

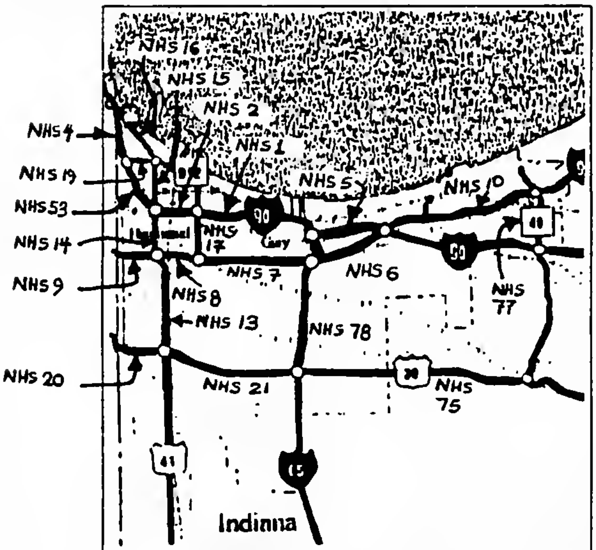
APPENDIX D2(a)
National Highway System, State of Indiana



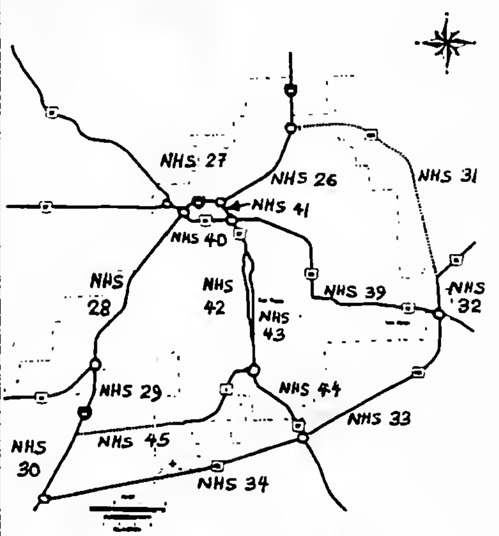
APPENDIX D2(b)
The National Highway System, State of Indiana
(based on the original submission)



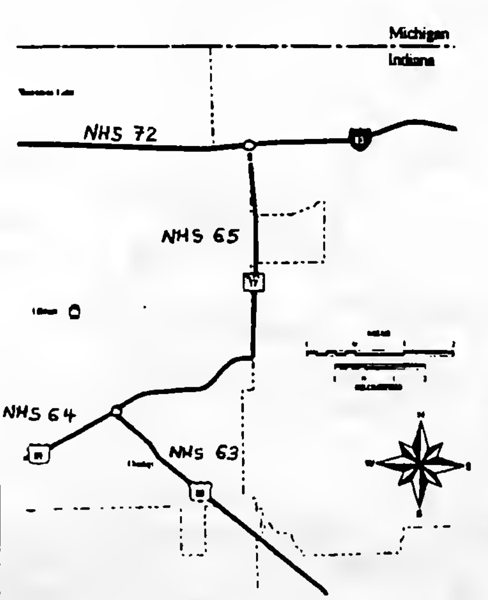
APPENDIX D2(c)
Details of the NHS at some metropolitan areas



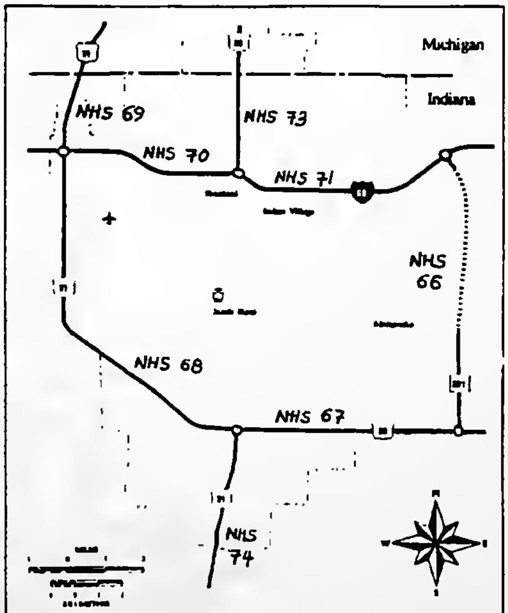
East Chicago Urbanized Area



Fort Wayne Urbanized Area

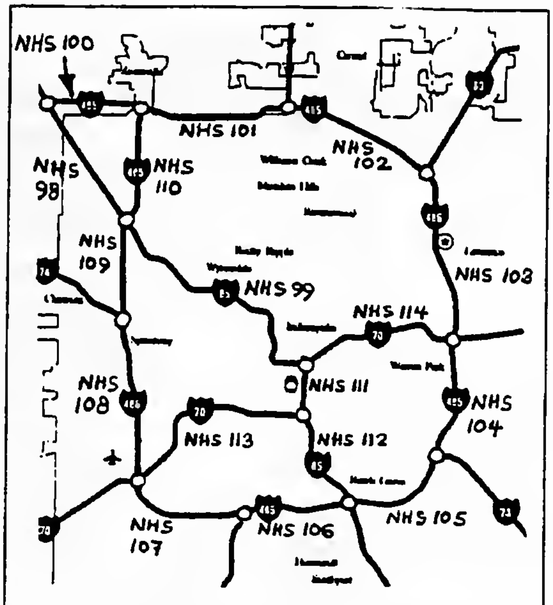


Elkhart-Goshen Urbanized Area

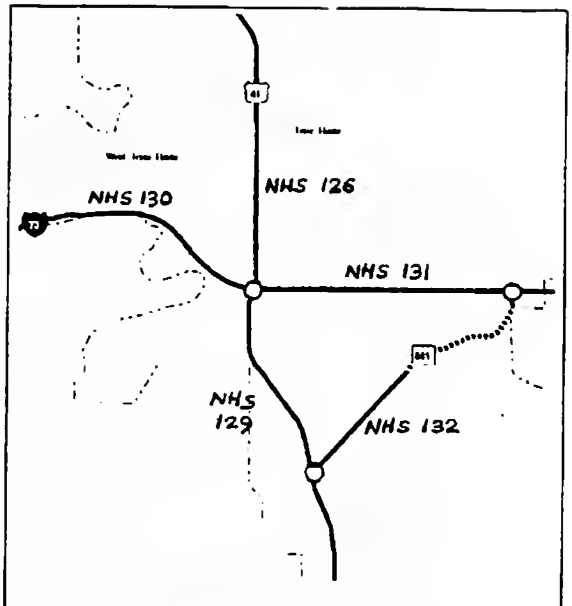


South Bend-Mishawaka Urbanized Area

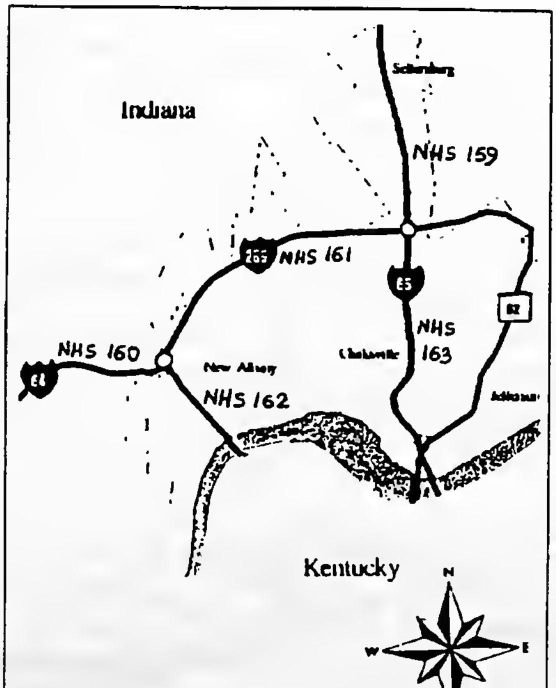
APPENDIX D2(d)
Details of the NHS at some metropolitan areas (continued)



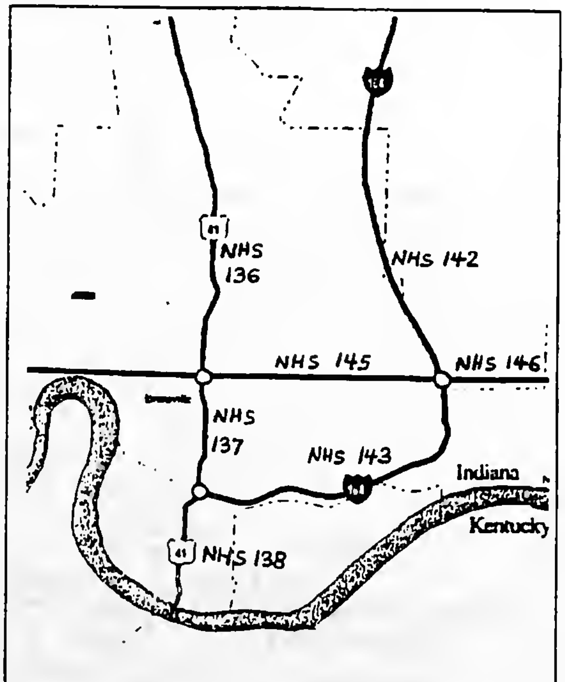
Indianapolis Urbanized Area



Terre Haute Urbanized Area

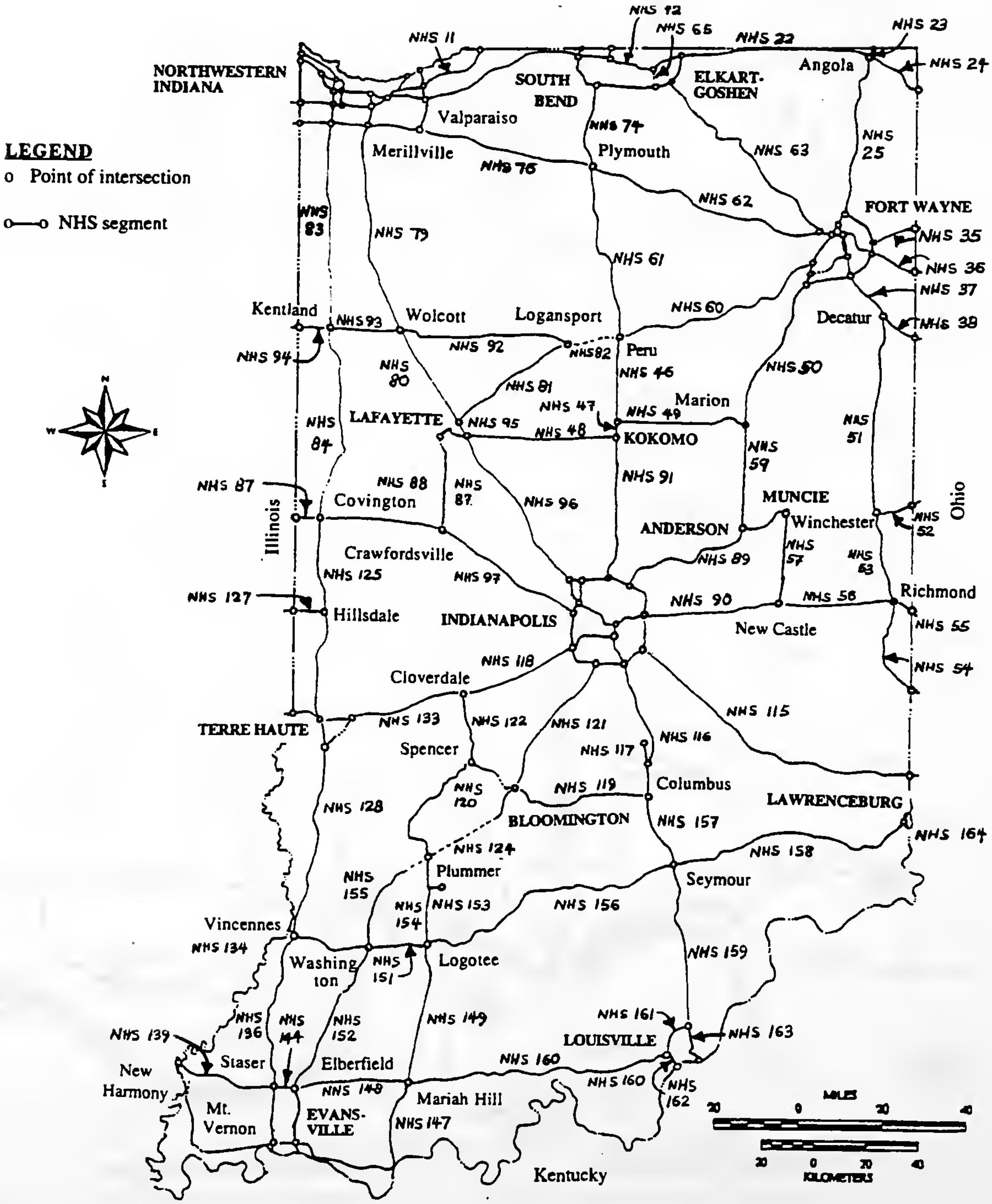


Louisville Urbanized Area

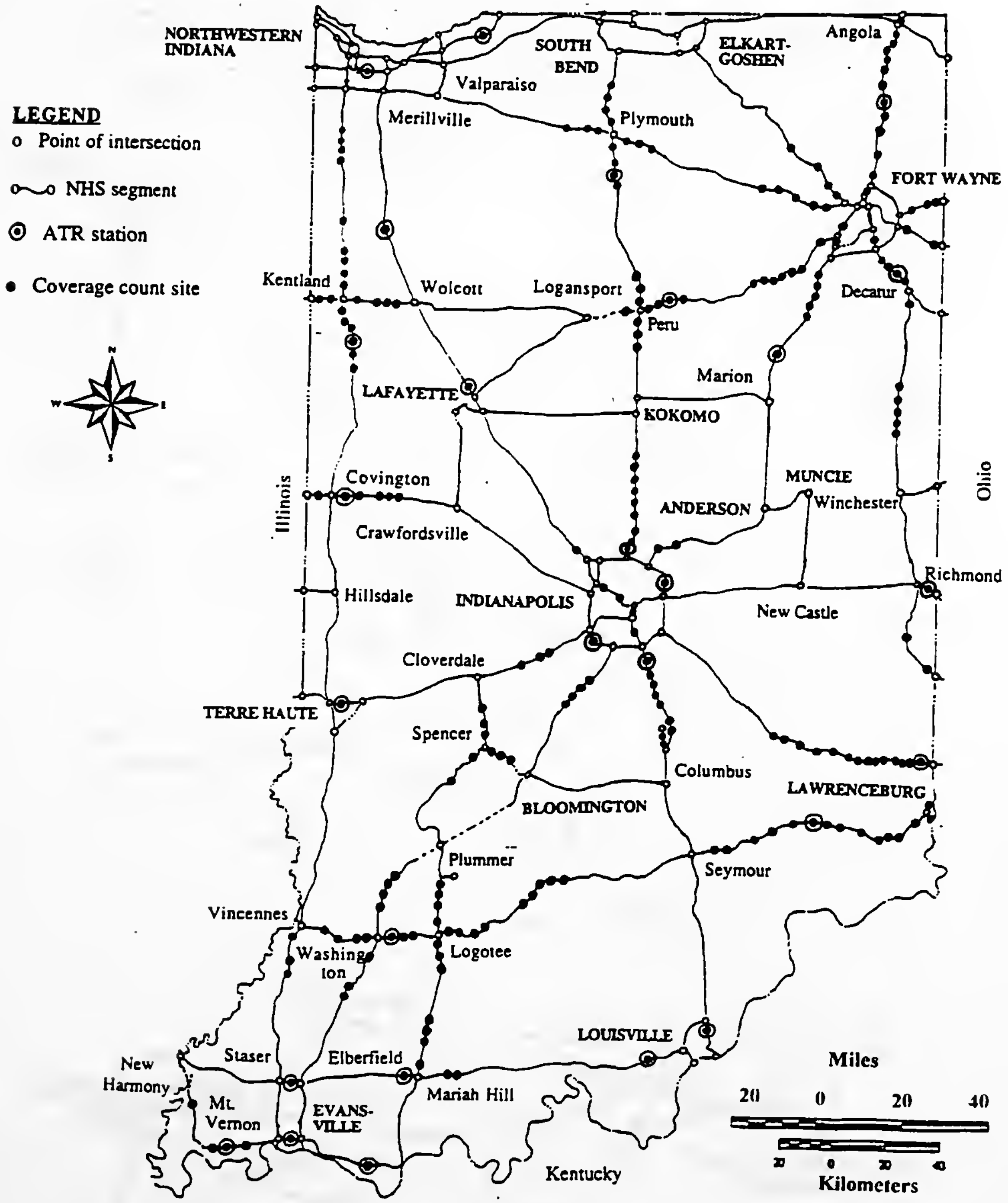


Evansville Urbanized Area

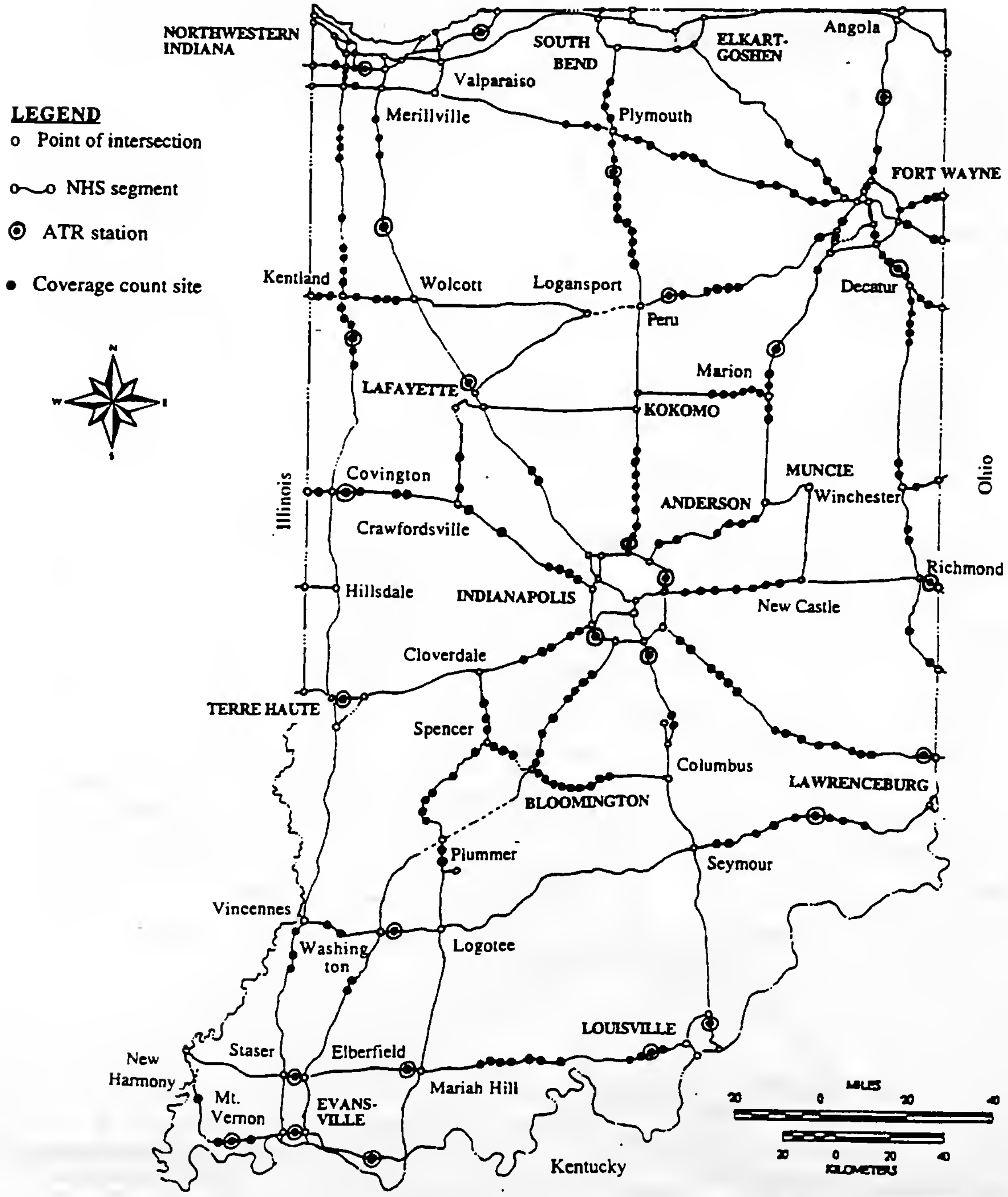
APPENDIX D2(e)
Numbered segments of the National Highway System



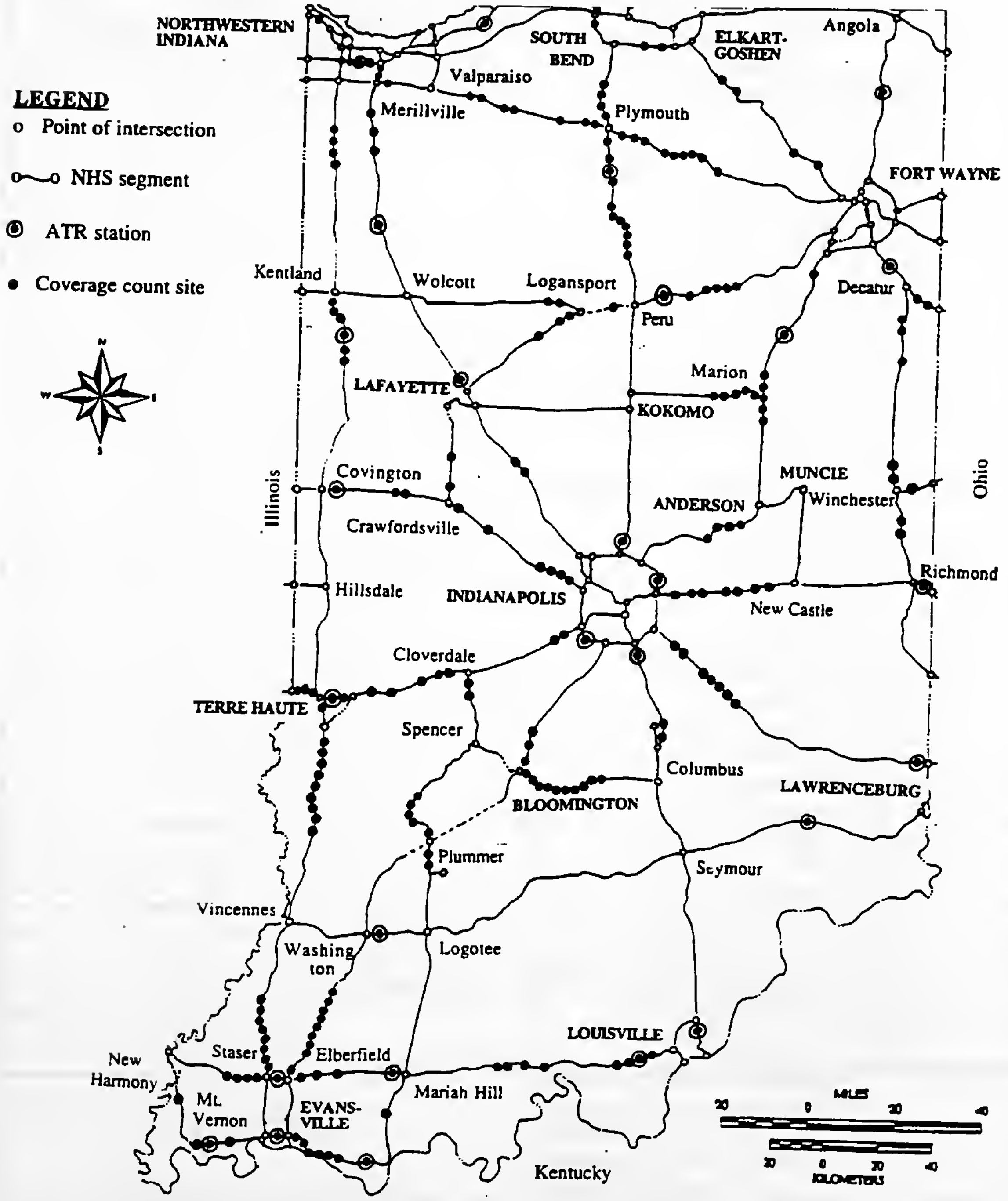
APPENDIX D2-f: Vehicle Classification Activities on the NHS, 1992-1994



APPENDIX D2(g): Vehicle Classification Activities on the NHS, 1993-1995



APPENDIX D2(h): Vehicle Classification Activities on the NHS, 1994-1996



APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA

Serial #	Description of Segment Road name, approx. length & end points	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 1	**Interstate Toll Road 90**, 6 miles *From* I-65 (Gary) *To* SR 912 (Hammond)	Lake 1995 (0350, 0370)	
NHS 2	**Interstate Toll Road 90,** 6 miles *From* SR 912 (Hammond) *To* SR 41 (East Chicago)		
NHS 3	**Interstate Toll Road 90**, 1 mile *From* SR 41 (East Chicago) *To* SR 912 (East Chicago)		
NHS 4	**Interstate Toll Road 90,** 4 miles *From* SR 912 (East Chicago) *To* Illinois border	Lake 1995 (0300)	
NHS 5	**Interstate Toll Road 90**, 5 miles *From* I-65 (Gary) *To* I-94 (Portage area)	Lake 1995 (0340, 0360)	
NHS 6	**Interstate Road 80/94**, 4 miles *From* I-65 (Gary) *To* I-90 (Portage area)	Tel 1400*	
NHS 7	**Interstate Road 80/94**, 6 miles *From* I-65 (Gary) *To* SR 912 (southern Hammond)	Lake 1995 (0260)	
NHS 8	**Interstate Road 80/94**, 2 miles *From* SR 912 (Hammond) *To* SR 41 (Hammond)	WIM 4440	
NHS 9	**Interstate Road 80/94**, 1 mile *From* SR 41(Hammond) *To* Illinois border		
NHS 10	**Interstate Road 94**, 9 miles *From* I-80/90 (west of Portage) *To* SR 49 (Chesterton)		
NHS 11	**Interstate Road 94**, 34 miles *From* I-90 (west of Portage) *To* Michigan border	WIM 4130, Tel 1120*	
NHS 12	**Interstate Toll Road 90**, 45 mi. *From* I-94 (west of Portage) *To* SR-31 (South Bend)		

APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA (cont'd)

Serial #	Description of Segment Road name, approx. length & end points.	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 13	**US Road 41,** 5 miles *From* US Road 30 (Schererville) *To* I-80/94 (Hammond)		
NHS 14	**US Road 41**, 4 miles *From* I-80/94 (Hammond) *To* I-90 (East Chicago)		
NHS 15	**US Road 41**, 1mile *From* I-90 (East Chicago) *To* SR 912 (East Chicago)		
NHS 16	**US Road 41**, 3 miles *From* SR 912 (East Chicago) *To* Illinois border		
NHS 17	**State Road 912**, 2 miles *From* I-80/94 (Hammond) *To* I-90 (East Chicago)	Lake 1995 (3090)	
NHS 18	**State Road 912**, 7 miles From I-90 (East Chicago) To US 41 (East Chicago)	Lake 1995 (3080)	
NHS 19	**State Road 912,** 1 mile *From* US 41 (East Chicago) *To* I-90 (East Chicago)		
NHS 20	**US Road 30**, 3 miles *From* US 41 (Schererville) *To* Illinois border		
NHS 21	**US Road 30**, 7 miles *From* US 41 (Schererville) *To* I-65 (Merillville)		
NHS 22	**Interstate Toll Road 80 / 90**, 70 mi. *From* CR-17 (South Bend) *To* I-69 (Angola)		
NHS 23	**Interstate Road 69**, 2 miles *From* I-90 (Angola) *To* Michigan border	WIM 4150 Steuben 1992 (0060)	
NHS 24	**Interstate Toll Road 80 / 90**, 14 miles *From* I-69 (Angola) *To* Ohio border		
NHS 25	**Interstate Road 69**, 40 miles *From* I-90 (Angola) *To* I-469 (Fort Wayne)	Allen 1993 (0070, 0080, 0090) Steuben 1992 (0010, 0020, 0030, 0040, 0050, 0060) Dearborn 1992 (0010, 0020, 0030, 0040, 0050)	
NHS 26	**Interstate Road 69**, 5 miles *From* I-469 (Fort Wayne) *To* US-27 (Fort Wayne)	Allen 1993 (0060)	

APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA (cont'd)

Serial #	Description of Segment Road name, approx. length & end points	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 27	**Interstate Road 69**, 3 miles *From* US-27 (Fort Wayne) *To* US-30 (Fort Wayne)		
NHS 28	**Interstate Road 69**, 8 miles *From* US-30 (Fort Wayne) *To* US-24 (Fort Wayne)	Tel 1420* Allen 1993 (0030)	
NHS 29	**Interstate Road 69**,3 miles *From* US-24 (Fort Wayne) *To* Baer Field Thruway i.e., SR-1 (Fort Wayne)	Allen 1993 (0040)	
NHS 30	**Interstate Road 69**, 3 miles *From* Baer Field Thruway, i.e., SR-1 (Fort Wayne) *To* I-469 (Fort Wayne)	Allen 1993 (1 count)	
NHS 31	**Interstate Road 469**, 12 miles *From* I-69 (Fort Wayne) *To* US-24 (New Haven)	Allen 1993 (1 count)	
NHS 32	**Interstate Road 469**, 2 miles *From* US-24 (New Haven) *To* US-30 (New Haven)	Allen 1993 (1 count)	
NHS 33	**Interstate Road 469**, 8 miles *From* US-30 (New Haven) *To* US-33 (Fort Wayne)		
NHS 34	**Interstate Road 469**, 11 miles *From* US-27 (Ft. Wayne) *To* US-69 (Ft. Wayne)		
NHS 35	**US Road 24**, 14 miles *From* I-469 (New Haven) *To* Ohio border	Allen 1993 (0240, 0260, 0270)	
NHS 36	**US Road 30**, 12 miles *From* I-469 (New Haven) *To* Ohio border	Allen 1993 (0421, 0450)	
NHS 37	**US Road 33**, 14 miles *From* I-469 (Ft. Wayne) *To* US-27 (Decatur)	WIM 4280 Allen 1993 (0280)	
NHS 38	**US Road 33,** 10 miles *From* US-27 (Decatur) *To* Ohio border	Adams 1995 (0160, 0200)	
NHS 39	**US Road 30**, 11 miles *From* I-469 (New Haven) *To* US-27 (Fort Wayne)		

APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA (cont'd)

Serial #	Description of Segment Road name, approx. length & end points	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 40	**US Road 30**, 2 miles *From* US-27 (Fort Wayne) *To* I-69 (Fort Wayne)		
NHS 41	**US Road 27**, 1 mile *From* I-69 (Fort Wayne) *To* US-30 (Fort Wayne)		
NHS 42	**US Road 27, west link**, 6 miles *From* US-30 (Fort Wayne) *To* Baer Field Thruway i.e., SR-1(Fort Wayne)		
NHS 43	**US Road 27, east link**, 6 miles *From* US-30 (Fort Wayne) *To* Baer Field Thruway i.e., SR-1(Fort Wayne)		
NHS 44	**US Road 27/33 Overlap Section**, 3 mi. *From* Baer Field Thruway i.e., SR-1 (Fort Wayne) *To* I-469 (Fort Wayne)		
NHS 45	**Baer Field Thruway**, i.e., SR-1, 8 mi. *From* US-27 (Fort Wayne) *To* I-69 (Fort Wayne)	Allen 1993 (0300)	Road section is partially constructed
NHS 46	**US Road 31**, 18 miles *From* US-24 (Peru) *To* US-35 (Kokomo)	Miami 1992 (0010, 0120, 0150, 0180)	
NHS 47	**US Road 31**, 4 miles *From* US-35 (Kokomo) *To* SR-26 (Kokomo)	Miami 1992 (0020)	
NHS 48	**State Road 26**, 37 miles *From* I-65 (Lafayette) *To* US-31 (Kokomo)	Tippecanoe 1994 (0971, 0980) Clinton (0182, 0200, 0230, etc.) Howard (0270)	
NHS 49	**US Road 35**, 26 miles *From* US-31 (Kokomo) *To* I-69 (Gas City)	Grant 1995 (5, 6, 7, 8, 9, 10)	
NHS 50	**Interstate Road 69**, 37 miles *From* US-35 (Gas City) *To* I-469 (Fort Wayne)	WIM 4140, Tel 1100* Grant 1995 (3, 4), Allen 1993 (0010) Huntington 1992 (0010, 0020, 0030, 0040)	
NHS 51	**US Road 27,** 48 miles *From* US-33 (Decatur) *To* SR-32 (Winchester	Adams 1995 (0010, 0060, 0070, 0080, 0090, 0131, 0140) Randolph 1995 (0080, 0054, 0010, 0031) Jay 1992 (0010, 0012, 0054, 0060, 0080)	
NHS 52	**State Road 32,** 2 miles *From* US-27 (Winchester) *To* Ohio border	Randolph 1995 (0522)	

APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA (cont'd)

Serial #	Description of Segment Road name, approx. length & end points	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 53	**US Road 27**, 24 miles. *From* SR-32 (Winchester) *To* I-70 (Richmond)	Randolph (0010, 0031) Wayne (0182, 0190)	
NHS 54	**US Road 27**, 9 miles *From* I-70 (Richmond) *To* Ohio border	Union 1993 (0012, 0070)	
NHS 55	**Interstate Road 70**, 5 miles. *From* US-27 (Richmond) *To* Ohio border	WIM 4280	
NHS 56	**Interstate Road 70**, 29 miles. *From* US-27 (Richmond) *To* SR-3 (New Castle)	5 coverage couns	
NHS 57	**State Road 3**, 20 miles. *From* I-70 (New Castle) *To* SR 67 (Muncie)	Tel 2530* Henry (0300, 0320) Delaware (0440, 0460)	
NHS 58	**State Road 67**, 12 miles. *From* SR-3 (Muncie) *To* I-69 (Anderson)		
NHS 59	**Interstate Road 69**, 25 miles *From* US-35 (Gas City) *To* SR-67 (Anderson)	Grant 1995 (2 count sites, station numbers not provided on checksheet)	
NHS 60	**US Road 24**, 56 miles *From* I-69 (Fort Wayne) *To* US-31 (Peru)	WIM 4270 Wabash 1995 (0010, 0020, 0030, 0040), Allen 1993 (0100) Miami 1992 (0030, 0050, 0051) Huntingtion 1992 (0060, 0080, 0100, 0110, 0120, 0160, 0162, 0170)	
NHS 61	**US Road 31**, 45 miles *From* US-24 (Peru) *To* US-30 (Plymouth)	WIM 4620, Tel 1230* Fulton 1995 (0010, 0011,0030, 0040, 0050, 0051, 0052, 0053, 0054, 0060) Marshall 1994 (0190, 0210, 0220) Miami 1992 (0120, 0230, 0250)	
NHS 62	**US Road 30**, 56 miles *From* US-31 (Plymouth) *To* I-69 (Fort Wayne)	Kosciusko 1995(0010, 0020, 0030, 0041, 0050, 0070) Marshall 1994 (0140, 0150, 0170) Whitley 1994 (0030, 0052, 0090, 0100) Allen 1993 (0360, 0361)	
NHS 63	**US Road 33**, 77 miles *From* US-30 (Ft. Wayne) *To* US 20 & CR 17 junction (Elkhart)	Elkhart 1996 (0300, 0442, 0450) Whitley 1994 (0120, 0170) Allen 1993 (0472, 0480)	

APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA (cont'd)

Serial #	Description of Segment Road name, approx. length & end points	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 64	**US Roads 20/ 33 overlap section**, 15mi *From* Capital Avenue i.e., SR 331 (South Bend) *To* US-33/CR-17 junction (Elkhart)		
NHS 65	**County Road 17**, 8 miles *From* US-20 & US-33 junction (Elkhart) *To* I-80/90 (Elkhart)		
NHS 66	**Capital Avenue** (formerly SR-331),7mi *From* US 33 (South Bend) *To* I-80 (South Bend)		Road section is partially constructed
NHS 67	**US Road 33**, 5 miles *From* US 31 (South Bend) *To* Capital Avenue i.e., SR 331 (South Bend)	St. Joseph 1996 (0520)	
NHS 68	**US Road 31**, 9 miles *From* US 33 (South Bend) *To* I-80/90 (South Bend)	Tel 1430* St. Joseph 1996 (0450)	
NHS 69	**US Road 31**, 2 miles *From* I-80/90 (South Bend) *To* Michigan border	St. Joseph 1996 (0410, 0460, 0470)	
NHS 70	**Interstate Road 80/90**, 4 miles *From* US 31 (South Bend) *To* US 33 (South Bend)		
NHS 71	**Interstate Road 80/90**, 5 miles *From* US 33 (South Bend) *To* Capital Avenue i.e., SR 331 (South Bend)		
NHS 72	**Interstate Road 80/90**, 10 miles *From* Capital Avenue i.e., SR 331 (South Bend) *To* CR-17 (Elkart)		
NHS 73	**US Road 33**, 3 miles *From* I-80/90 (South Bend) *To* Michigan border		
NHS 74	**US Road 31**, 32 miles *From* US 33 (South Bend) *To* US-30 (Plymouth)	Marshall 1994 (0250, 0234, 0260) St. Joseph 1995 (0410)	
NHS 75	**US Road 30**, 17 miles *From* SR-49 (Valparaiso) *To* I-65 (Merillville)	Porter 1994 (0320, 0325)	
NHS 76	**US Road 30**, 43 miles *From* US-31 (Plymouth) *To* SR-49 (Valparaiso)	Tel 1210* Laporte 1996 (0430, 0460, 0490) Marshall 1994 (0100, 0110, 0130) Porter 1994 (0380)	

APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA (cont'd)

Serial #	Description of Segment Road name, approx. Length & end points	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 77	**State Road 49**, 9 miles *From* I-90 (Chesterton) *To* US-30 (Valparaiso)	WIM 4240 Porter 1994 (0660, 0661, 0662. 0670)	
NHS 78	**Interstate Road 65**, 7 miles *From* I-90 (Gary) *To* US-30 (Merillville)	2 coverage counts	
NHS 79	**Interstate Road 65**, 58 miles. *From* US-30 (Merillville) *To* US 24 (Wolcott)	WIM 4110, Tel 1410* 4 coverage counts	
NHS 80	**Interstate Road 65**, 26 miles. *From* US-24 (Wolcott) *To* SR 25 (Lafayette)	WIM 5450. 2coverage counts	
NHS 81	**State Road 25**, 35 miles. *From* I-65 (Lafayette) *To* SR-26 (Logansport)	Cass 1996 (0550, 0560, 0570)	
NHS 82	**US Road 24**, 15 miles. *From* SR-25 (Logansport) *To* US-31 (Peru)	Cass 1996 (0160) Miami 1992 (0010)	
NHS 83	**US Road 41**, 56 miles *From* I-80 (Gary) *To* US-24 (Kentland)	Newton 1993 (0121, 0140, 0160, 0170, 0182, 0210)	
NHS 84	**US Road 41**, 47 miles *From* US-24 (Kentland) *To* 1-74 (Covington)	WIM 5240 Benton 1996 (0010, 0020, 0040, 0060, 0080), Newton 1993 (0100)	
NHS 85	**Interstate Road 74**, 5 miles *From* US-41 (Covington) *To* Illinois border		
NHS 86	**Interstate Road 74**, 30 miles *From* US-41 (Covington) *To* US-231 (Crawfordsville)	WIM 5130 Montgomery 1995 (0010, 0020) Fontain 1992 (0010, 0020, 0030)	
NHS 87	**State Road 26**, 4 miles. *From* I.-65 (Lafayette) *To* US 231 (Lafayette)		
NHS 88	**US Road 231**, 26 miles *From* SR 26 (Lafayette) *To* I-74 (Crawfordsville)	Tel 2230* Tippecanoe 1994 (0250, 0270, 0275) Montgomery 1995 (0250, 0260)	Road section is partially constructed
NHS 89	**Interstate Road 69**, 36 miles *From* SR-67 (Anderson) To I-465 (Indianapolis)	Madison 1995 (0010, 0020, 0030, 0040) Hamilton 1993 (0030, 0040)	
NHS 90	**Interstate Road 70**, 36 miles *From* SR-3 (New Castle) *To* I-465 (Indianapolis)	Tel 2110* Hancock 1995 (0010, 0020, 0030)	

APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA (cont'd)

Serial #	Description of Segment Road name, approx. length & end points	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 91	**US Road 31**, 38 miles *From* SR-26 (Kokomo) *To* I-465 (Indianapolis)	WIM 5550 Hamilton 1993 (0103, 0131, 0160, 0180) Tipton 1993 (0010, 0020,0030, 0040)	
NHS 92	**US Road 24**, 42 miles *From* SR-25 (Logansport) To I-65 (Wolcott)	Cass (0010, 0020) White (0050, 0071, 0091, etc.) Jasper (0120)	
NHS 93	**US Road 24**, 17 miles. *From* I-65 (Wolcott) *To* US-41 (Kentland)	Newton 1993 (0040, 0050, 0060, 0080)	
NHS 94	**US Road 24**, 5 miles. *From* US-41 (Kentland) *To* Illinois border	Newton 1993 (0010, 0020)	
NHS 95	**Interstate Road 65**, 3 miles *From* SR-25 (Lafayette) *To* SR-26 (Lafayette)		
NHS 96	**Interstate Road 65**, 42 miles *From* SR-26 (Lafayette) *To* I-465 (Exit 129, near Royalton, Indy)	Clinton 1995 (0010, 0020) Marion 1992 (0210, 0420)	
NHS 97	**Interstate road 74**, 40 miles. *From* US-231 (Crawfordsville) *To* I-465 (Exit 16/73, near Speedway, Indianapolis)	Hendricks 1995 (0050, 0060, 0070, 0080) Montgomery 1995 (0030, 0040)	
NHS 98	**Interstate Road 65**, 5 miles. *From* I-465 (Exit 129, near Royalton, Indianapolis *To* I-465 (Exit 20/123, near North Westway Park, Indianapolis)	Tel 2400* Marion 1992 (0190, 0200)	
NHS 99	**Interstate Road 65**, 8 miles. *From* I-465 (Exit 20/123, near North Westway Park, Indianapolis) *To* I-70 (Exit 112, near Morris Butler Museum, Indianapolis)	Marion 1992 (0100, 0180)	
NHS 100	**Interstate Road 465**, 5 miles *From* I-65 (Exit 129, near Royalton, Indy) *To* I-465 South (Exit 25, Zionsville, Indianapolis)	Marion 1992 (0660)	
NHS 101	**Interstate Road 465**, 6 miles *From* I-465 South (Exit 25, Zionsville, Indianapolis) *To* SR-31 (Exit 31, near Homeplace, Indianapolis)		

APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA (cont'd)

Serial #	Description of Segment Road name, approx. length & end points	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 102	**Interstate Road 465**, 7 miles. *From* SR-31, (Exit 31, near Homeplace, Indianapolis) *To* I-69 (Exit 37, near Castleton, Indianapolis)		
NHS 103	**Interstate Road 465**, 5 miles. *From* I-69 (Exit 37, near Castleton, Indianapolis) To I-70 (Exit 40/90, near Warren Park, Indianapolis)	WIM 5480	
NHS 104	**Interstate Road 465**, 5 miles *From* I-70 (Exit 40/90, near Warren Park, Indianapolis) *To* I-74 (Exit 49/94, near County Fair Grounds Indianapolis)	Tel 2420*	
NHS 105	**Interstate Road 465**, 5 miles *From* I-74 (Exit 49/94, near County Fair Grounds, Indianapolis) *To* I-65 (Exit 54/106, near Beech Grove, Indianapolis)		
NHS 106	**Interstate Road 465**, 4 miles *From* I-65 (Exit 54/106, near Beech Grove, Indianapolis) *To* SR-37 (Exit 4, Belmont Avenue, Indianapolis)		
NHS 107	**Interstate Road 465**, 4 miles *From* SR-37 (Exit 4, near Sunshine Gardens, Indy) *To* I-70, (Exit 9/73, near Airport, Indy)	WIM 5460	
NHS 108	**Interstate Road 465**, 6 miles *From* I-70, (Exit 9/73, near Airport, Indy) *To* I-74 (Exit 16/73, near Speedway, Indy)		
NHS 109	**Interstate Road 465**, 4 miles *From* I-74 (Exit 16/73, near Speedway, Indy) *To* I-65, (Exit 20/123, near North Westway Park, Indy)	WIM 4140	

APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA (cont'd)

Serial #	Description of Segment Road name, approx. length & end points	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 110	**Interstate Road 465**, 5 miles *From* I-65 (Exit 20/123, near North Westway Park, Indy) *To* I-465 West (Exit 25, Zionsville, Indy)		
NHS 111	**Interstate Road 65,** 2 miles. *From* I-70 (Exit 112, near Morris Butler Museum, Indy) *To* I-70 (Exit 110, near Garfield Park, Indy)	WIM 5480	
NHS 112	**Interstate Road 65**, 4 miles *From* I-70 (Exit 110, near Garfield Park, Indianapolis) *To* I-465 (Exit 107, near Beech Grove Indy)		
NHS 113	**Interstate Road 70**, 7 miles *From* I-465 (Exit 9/73, near Airport, Indy) *To* I-65 (Exit 110, near Garfield Park, Indy)	Marion 1992 (0350)	
NHS 114	**Interstate Road 70**, 8 miles *From* I-65 (Exit 110, near Brookside Park, Indy) *To* I-465 (Exit 9/93, near Airport Indy)		
NHS 115	**Interstate Road 74**, 80 miles *From* I-465 (Exit 49/94, near Marion County Fairgrounds, Indy) *To* Ohio border	WIM 6170, Tel 3100 Ripley 1993 (0010, 0020, 0030) Shelby 1995 (0010, 0020, 0040, 0050, 0060, 0070, 0080, 0090, 0100) Dearborn 1992 (0010, 0020, 0030) Franklin 1992 (0010, 0020) Marion 1992 (0460, 0470, 0480)	
NHS 116	**Interstate Road 65**, 40 miles. *From* I-465 (Exit 54/106, near Beech Grove, Indy) *To* SR-46 (Columbus)	WIM 5470 Johnson 1992 (0010, 0020, 0030)	
NHS 117	**US Road 31**, 15 miles *From* I-65 (Columbus) *To* SR-44 (Franklin Military Base)	Johnson 1992 (0060, 0080, 0100, 0103)	
NHS 118	**Interstate Road 70**, 32 miles *From* I-465, (Exit 9/73, Airport area, Indianapolis) *To* US-231 (Cloverdale)	Hendricks 1995 (0010, 0020) Morgan 1993 (0010, 0020, 0030) Marion 1992 (0420)	

APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA (cont'd)

Serial #	Description of Segment Road name, approx. length & end points	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 119	**State Road 46**, 36 miles. *From* I-65 (Columbus) *To* SR-37 (Bloomington)	Tel 2910*, Tel 2920* Monroe 1995 (0260, 0290, 0300) Brown 1996 (0040, 0042, 0060, 0070, 0080, 0090)	
NHS 120	**State Road 46**, 16 miles *From* SR-37(Bloomington) *To* US-231 (Spencer)	Monroe 1995 (0250) Owen 1993 (0220, 0240)	Road section is partially constructed
NHS 121	**State Road 37**, 40 miles *From* I-465 (near Belmont Ave., Indianapolis) *To* SR-46 (Bloomington)	Tel 2410* Monroe 1995 (0070, 0090, 0120) Morgan 1993 (0050, 0060, 0070, 0080, 0111, 0120) Marion 1992 (1350) Johnson 1992 (0150, 0161, 0170)	
NHS 122	**US Road 231**, 18 miles *From* I-70 (Cloverdale) *To* SR-46 (Spencer)	Putnam 1996 (0190, 0213) Owen 1993 (0060, 0070, 0080)	
NHS 123	**US Road 231**, 29 miles *From* SR-46 (Spencer) *To* SR-57 (Plummer)	Green 1995 (0050, 0060, 0080, 0120) Owen 1993 (0010, 0020)	
NHS 124	**State Road 57**, 25 miles *From* US-231 (Plummer) *To* SR-467 (Bloomington)		Road section is partially constructed
NHS 125	**US Road 41**, 38 miles *From* I-74 (Covington) *To* US-36 (Hillsdale)	Parke (0120, 0130, 0160) Fountain (0040, 0060, 0070, 0100)	
NHS 126	**US Road 41**, 25 miles *From* US-36 (Hillsdale) *To* I-70 (Terre Haute)	Vigo 1996 (0360, 0354, 0352)	
NHS 127	**US Road 36**, 6 miles. *From* SR-63 (Hillsdale) *To* Illinois border	Vermillion (0040, 0050, 0060)	
NHS 128	**US Road 41**, 57 miles. *From* I-70 (Terre Haute) *To* US-50 (Vincennes)	Tel 2520* Sullivan 1996 (0010, 0020, 0040, 0050, 0060, 0080, 0090, 0110, 0120) Vigo 1996 (0227) Knox 1993 (0120, 0130, 0160)	
NHS 129	**US Road 41**, 3 miles. *From* I-70 (Terre Haute) *To* SR 641 (Terre Haute)	Vigo 1996 (0351)	
NHS 130	**Interstate Road 70**, 5 miles. *From* US 41 (Terre Haute) *To* Illinois border	Vigo 1996 (0010, 0020, 0030)	

APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA (cont'd)

Serial #	Description of Segment Road name, approx. length & end points	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 131	**Interstate Road 70**, 4 miles. *From* US 41 (Terre Haute) *To* SR 641 (Terre Haute)	Vigo 1996 (0050)	
NHS 132	**State Road 641**, 5 miles. *From* US 41 (Terre Haute) *To* I.-70 (Terre Haute)		Road section is partially constructed
NHS 133	**Interstate Road 70**, 15 miles *From* SR-63 (Terre Haute) *To* US-231 (Cloverdale)	WIM 5440, Tel 2100*, Tel 2430* Clay 1995 (0010, 0020) Putnam 1996 (0010, 0020, 0030)	
NHS 134	**US Road 41**, 2 miles *From* US-50 (Vincennes) *To* Illinois border	Knox 1993 (0180)	
NHS 135	**US Road 41**, 42 miles *From* US-50 (Vincennes) *To* I-64 (Warrenton)	Tel 3340* Gibson 1996 (0090, 0100, 0101, 0102, 0110, 0120, 0121, 0140, 0150, 0160, 0170, 0180, 0190) Knox 1993 (0010, 0030)	
NHS 136	**US Road 41**, 16 miles *From* I-64 (Warrenton) *To* SR-62 (Evansville)	Tel 3240* Vanderburg (0262)	
NHS 137	**US Road 41**, 2 miles *From* SR 66 (Evansville) *To* I.-164 (Evansville)		
NHS 138	**US Road 41**, 2 miles *From* I-64 (Evansville) *To* Kentucky border	Tel 3520* Vanderburg (0160)	
NHS 139	**Interstate Road 64**, 28 miles *From* US-41 (Warrenton) *To* Illinois border	Gibson 1996 (0010) Vanderburgh 1996 (0010, 0020)	
NHS 140	**State Road 62**, 12 miles *From* US-41 (Evansville) *To* SR 69 (Mt. Vernon)	Posey 1994 (0070, 0100)	
NHS 141	**State Road 69**, 12 miles *From* SR 62 (Mt. Vernon) *To* I-64 (Griffin)	WIM 6250 Posey 1994 (0374)	
NHS 142	**Interstate Road 164**, 14 miles *From* I-64 (Elberfield) *To* SR-66 (Evansville)		
NHS 143	**Interstate Road 164**, 6 miles *From* SR-66 (Evansville) *To* US-41 (Evansville)		
NHS 144	**Interstate Road 64**, 4 miles *From* US-41 (Warrenton) *To* I-164 (Elberfield)	WIM 6140 Gibson 1996 (0020, 0030) Vanderburgh 1996 (0030, 0040)	

APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA (cont'd)

Serial #	Description of Segment Road name, approx. length & end points	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 145	**State Road 66**, 5 miles *From* SR 41 (Evansville) *To* I-164 (Evansville)	WIM 6270 Warrick 1996 (0470, 0471, 0490, 0500, 0510, 0520)	
NHS 146	**State Road 66,** 25 miles *From* I-164 (Evansville) *To* US 231 (Rockport)	Warrick (0470, 0471, 0490, etc.) Spencer (0400, 0420)	
NHS 147	**US Road 231**, 20 miles *From* SR 66 (Rockport) *To* I-64 (Dale)	Warrick 1996 (0110)	
NHS 148	**Interstate Road 64**, 28 miles. *From* I-164 (Elberfield) *To* US-231 (Dale)	WIM 6150 Warrick 1996 (0010, 0020, 0030, 0040)	
NHS 149	**US Road 231**, 46 miles *From* I-64 (Dale) *To* US-50 (Logotee)	Dubois 1992 (5 counts, station numbers not indicated on checksheet Martin 1992 (0210, 0211, 0212)	
NHS 150	**US Road 50**, 28 miles *From* SR-57 (Washington) *To* US-41 (Vincennes)	Knox 1993 (0200, 0230, 0240) Daviess 1992 (0100, 0105)	
NHS 151	**US Road 50**, 15 miles *From* SR-57 (Washington) *To* US-231 (Logotee)	WIM 6280 Daviess 1992 (0070, 0080, 0090)	
NHS 152	**State Road 57**, 41 miles *From* US-50 (Washington) *To* I-64 (Elberfield)	Gibson 1996 (0240, 0250, 0260, 0270, 0280, 0290, 0300, 0310, 0320) Pike 1993 (0130, 0180) Daviess 1992 (0190)	
NHS 153	**State Road 558**, 2 miles *From* US-231 (near Farlen) *To* Crane Military Center		
NHS 154	**US Road 231**, 21 miles *From* US-50 (Logotee) *To* SR-57 (Plummer)	Green 1995 (0100, 0020) Daviess 1992 (0110, 0120, 0140, 0170) Martin 1992 (0240)	
NHS 155	**State Road 57**, 28 miles *From* US-50 (Washington) *To* US-231 (Plummer)	Daviess 1992 (0215, 0240, 0300)	Road section is partially constructed
NHS 156	**US Road 50**, 71 miles *From* US-231 (Logotee) *To* US-50/ I-65 (Seymour)	Lawrence 1992 (0011, 0012, 0020, 0032, 0060, 0105, 0110, 0120, 0130) Martin 1992 (0071, 0080, 0111, 0140)	
NHS 157	**Interstate Road 65**, 19 miles. *From* US-50 (Seymour) *To* SR-46 (Columbus)		

APPENDIX D2(i): SEGMENTS OF THE NATIONAL HIGHWAY SYSTEM IN THE STATE OF INDIANA (cont'd)

Serial #	Description of Segment Road name, approx. length & end points	Vehicle classification ATR sites, HPMS and CFM coverage sites located on NHS segment	Remarks
NHS 158	**US Road 50**, 63 miles *From* I-65 (Seymour) *To* I-275 (Lawrenceburg)	WIM 6290, Tel 3210* Ripley 1993 (0050, 0100, 0120, 0140) Jennings 1993 (0100, 0020, 0030, 0060) Dearborn 1992 (0100, 0110, 0120, 0123)	
NHS 159	**Interstate Road 65**, 43 miles *From* US-50 (Seymour) *To* I-265 (Louisville)	WIM 6420, Tel 3110*	
NHS 160	**Interstate Road 64**, 65 miles *From* US-231 (Dale) *To* I-265 (Louisville)	WIM 6160, Tel 3120* Crawford 1995 (0010, 0020, 0030) Perry 1993 (0010, 0020, 0030) Dubois 1992 (2 counts, station numbers not indicated on checksheet)	
NHS 161	**Interstate Road 265**, 6 miles *From* I-65 (Louisville) *To* I-64 (Louisville)	Tel 3400* Harrison 1995 (0010, 0020, 0030)	
NHS 162	**Interstate Road 64**, 3 miles *From* I-265 (Louisville) *To* Kentucky border		
NHS 163	**Interstate Road 65**, 6 miles *From* I-264 (Louisville) *To* Kentucky border	Tel 3410*	
NHS 164	**Interstate Road 275**, 4 miles *From* Kentucky border (Lawrenceburg) *To* Ohio border (Lawrenceburg)	Dearborn 1992 (0060, 0070)	

DRAFT TMS/H Data Action Plan **E**
Vehicle occupancy monitoring
Jon D. Fricker
September 21, 1998

INDOT Work Plan Activity: *Define needs/processes and frequency for vehicle occupancy monitoring*

23 CFR Chapter 1,
Subchapter F (Transportation and Infrastructure Management), Part 500 (Management and Monitoring Systems), Subpart H (Traffic Monitoring Systems for Highways), Section 500.807(e), *Federal Register*, 1 December 1993, p. 63484: "... data will be collected on the average number of persons per automobile, light two-axle truck, and bus. The duration, geographic extent, and level of detail shall be consistent with the intended use of the data, as cooperatively agreed to by the organizations that will use and the organizations that will collect the data."

Frequency: "... minimum of every three years and updated as necessary."

Acceptable data collection methods: "include roadside monitoring, traveler surveys, ... accident reports ... or any other method mutually acceptable to the responsible organizations and the FHWA."

Additional guidance in FHWA White Paper dated Mar 17 1994, "Initial Issues Related to the Development of a Traffic Monitoring System for Highways", distributed by the Director, Office of Highway Information Management to Regional Federal Highway Admionistrators:

- "Section 500.807(e) ... does not call for widespread collection of vehicle occupancy data."
- "... need to have data that will properly reflect the person miles of travel being served by the highway system."
- "The importance of such data in making investment decisions between both highway and non-highway alternatives and thus the resulting detail at which it needs to be collected will vary depending on local circumstances."

A. TRAFFIC DATA NEEDS

1. **Type of traffic data required.** The average number of persons per vehicle has the following uses:
   a. Helping transportation demand modelers convert person-trips into vehicle-trips some time before the traffic assignment step.
   b. Providing a local basis for (or check on) the relationship between person-based trip generation and vehicle-based traffic impact data.
   c. Assessing the need for, or the effectiveness of, ridesharing programs.
   d. Measuring the (potential) success of programs designed to improve air quality and/or alleviate congestion.
   e. Monitoring trends in travel behavior with respect to group size in private vehicles.

   Vehicle occupancy data does not include common carrier vehicles such as public transit vehicles or intercity buses. These are included in the Public Transportation Facilities and Management System (PTMS) in DAP B6.

2. **Required location of data collection sites.**
   a. For travel demand modeling in urban areas, vehicle occupancies are most useful at *screenlines*, where modelers are concerned with matching modeled flows against observed flows. Typically, screenline locations are at river or major railroad crossings. However, vehicle occupancy rates at other locations or on an areawide basis are also acceptable to a modeler.
   b. Average vehicle occupancy for traffic impact analysis purposes is, of course, most useful at land use types that match the site being analyzed. The rate for a furniture store may be much different from that of a fast-food restaurant. A work trip and a school trip are likely to have different rates as well. The analyst must decide if these differences are sufficiently large to justify detailed data collection efforts.
   c. If the ridesharing program of interest includes dedicated lanes for higher-occupancy vehicles, monitoring the average number of persons per vehicle on these facilities is rather straightforward. In the absence of such facilities, an areawide data collection effort is called for.
   d. Efforts to increase vehicle occupancy to improve air quality often focus on major employment and commercial centers. These locations can be spot checked on a regular basis.
   e. Even if none of the specific activities listed above make average occupancy rates a concern to an area's transportation data collectors or users, a periodic sampling of vehicle occupancy would be a good idea. At a minimum, it would alert local transportation planners to possible changes in travel behavior and enable the planners to relate local data to data borrowed from other locations.

3. **Minimum frequency and duration of data collection.**
   a. Although an annual update of average vehicle occupancy may be useful to the travel demand modeler, this information is not essential until an official update of a transportation plan is undertaken. This may be every several years, depending on the governing legislation and other factors.
   b. Depending on the analyst's judgment, a vehicle occupancy study may not be needed at all. If such a study is thought to be useful, it will be done on a site-specific basis.
   c. If enforcing minimum vehicle occupancy on a specific facility is the issue, this will be done on an ongoing basis as part of the facility's normal operation. In other locations, the data collection will be similar to that in part a above.
   d. For air quality programs, vehicle occupancy checks will be unannounced and at irregular intervals. Because these checks are not specifically for traffic purposes, they may be carried out (and be funded) by an agency other than a highway agency, unless special arrangements are made.
   e. See part a above.

B. INFORMATION ON THE EXISTING SITUATION

1. **Data collection equipment and sites.**
   Traditional data collection for vehicle occupancy has involved human observers making written notations. Variations may have included audio recordings or even video tapes of vehicles in the traffic stream at selected locations. Sites were chosen to meet specific needs (see screenlines, impact studies, and employment centers above) and to comprise a "representative" sample of the entire population of vehicles of concern.
2. **Data collection personnel.**

For small studies of vehicle occupancy that did not justify training temporary help, agency personnel were used to make the observations. If audio or video tapes were used, agency staff or individuals hired for the purpose "reduced" the audio or video information into numerical data for appropriate agency analysis.

C. EVALUATION OF THE EXISTING SITUATION

For several reasons, the collection of vehicle occupancy data has not had a high priority among those agencies that might be expected to have a use for it.

(1) It is tedious to collect. Even with audio or video tape, there is a significant amount of human effort involved.
(2) Except for a few specific applications, modelers have felt comfortable in using vehicle occupancy rates borrowed from national sources or other local areas.
(3) Direct vehicle count data is sufficient for many transportation planning and traffic engineering applications.
(4) When vehicle occupancy is important, it is often connected to the enforcement of the use of higher-occupancy vehicle lanes or mandated minimum persons per vehicle in a non-attainment area. These data collection efforts are likely to be carried out as part of the HOV facility's or the air quality agency's operation.

Several "secondary" sources of vehicle occupancy data are available.

- The 1990 Census long form question 23b was "How many people, including this person, usually rode to work in the car, truck, or van LAST WEEK?" Responses are summarized on CD-ROM in journey-to-work (JTW) tables for urban areas. Note, however, that these data are for work trips only, which make up only about 20 percent of all trips made by a household.
- The 1990 Nationwide Personal Transportation Survey (NPTS) asked about household members (questions h9-h12) and non-household members (questions g20-g23) that went on a trip with person being interviewed, but these data have clear statistical reliability only at the regional (multi-state) level.
- Among MPOs in Indiana, NIRCC has done small-scale occupancy studies at entrances to specific sites (major employers, shopping centers, medical centers and schools, but none since the late 1980s. Tippecanoe County's APC has done occupancy checks on specific network elements, such as bridges crossing the Wabash River. KIPDA (with TARC) has had several survey efforts since 1990, during which occupancy data were collected. These could be shared with other Indiana MPOs, with the risk associated with any data that are transferred to other areas.
- In the report of ITE Committee 6Y-46 "Urban Travel Characteristics Database" (ITE Publication No. IR-078), some contributing urban areas have offered their occupancy survey findings, which could be used for comparison purposes. In addition, the report of ITE Committee 6Y-53 "Travel Demand Forecasting Processes Used by Ten Large Metropolitan Planning Organizations" (ITE Publication No. IR-086) contains values and models for auto occupancy. However, the sources of the 6Y-53 data do not match the characteristics of most Indiana urban areas and the 6Y-46 data base does not claim to be a representative sample of US travel behavior – at least not until more data are contributed.
- Indiana public transportation systems routinely collect and report "Total passenger boardings" and "Revenue vehicle-miles (RVM)", but a special survey would be needed to

estimate "Average trip length" or "Total passenger miles (TPM)". For example, TPM/RVM would give an average occupancy.

Some newer technologies promise to make "roadside monitoring" more efficient by using video methods. Methods employing radar, infrared, and heat imaging methods are being developed, but their costs and reliability have not yet been adequately assessed. There also may be issues of privacy to resolve. "A Procedure To Calculate Vehicle Occupancy Rates From Traffic Accident Data", an April 1991 report by Connecticut DOT's Bureau of Planning, demonstrated surprising good results. Using the statewide traffic accident database, Connecticut was able to compute occupancy rates that were facility-specific, time-of-day-specific, and location-specific. When occupancy rates from other methods were available, the values were quite close. Furthermore, the occupancy data can be generated without special studies being planned and executed. The savings in staff time and other resources in conducting an occupancy survey at selected sites were significant. The report addresses possible biases in using crash records, and finds that they are not significant.

D. RECOMMENDED DATA ACTION PLAN FOR WORK PLAN ACTIVITY E

1. INDOT should maintain contacts with MPOs, so that any vehicle occupancy information collected by MPOs is shared with INDOT.
2. MPOs should be encouraged to include questions about occupancy in any relevant surveys done in the future. These efforts by MPOs would cover the major urban areas in Indiana. As MPOs undertake updates of their long-range plans, INDOT should strive to incorporate occupancy data generated by the MPOs. However, these INDOT activities are more likely to fall within the activities of the Planning and Programming Division than with Roadway Management.
3. INDOT does have not appear to have a pressing need for vehicle occupancy data on non-urban roadways. To the extent that it does, it would be as part of the development and maintenance of the statewide model. Use of the Indiana Crash Database would be an efficient way to generate suitable statewide occupancy data that would reduce the number of special on-site occupancy studies that would be needed.
4. An occasional vehicle occupancy study at a representative set of sites may be carried out to validate use of the crash database, especially if the three-year reporting cycle in the original TMS/H requirements are to be followed.

Draft TMS/H Data Action Plan F
Validation /accuracy, testing of equipment
Amr Mahmoud and Jon Fricker
September 21, 1998

23 CFR Chapter 1
Subchapter F
Part 500 (Management and Monitoring Systems)
Subpart H (Traffic Monitoring Systems for Highways)
Section 500.807 (f)

INDOT Work Plan Activity: *Validation / accuracy of existing traffic counting equipment including preparation of procedural guidelines for equipment testing.*

Principal application "...Only equipment passing the test procedures will be used for the collection of data".

In the December 1993 issue of the Federal Register, Traffic Monitoring System for Highways (TMS/H) was defined as " A systematic process for the collection, analysis, summary, and retention of highway related person and vehicular data, including public transportation on public highways and streets". Subpart F in the Federal register deals with field operations and it requires that "Each State's TMS/H shall include the testing of equipment used in the collection of highway traffic data. The testing shall be based on documented procedures developed by the State. This documentation will describe the test procedure as well as the frequency of testing. ... Only equipment passing the test procedures will be used for the collection of data...".

A. INFORMATION ON THE EXISTING SITUATION

Currently, there are 33 weigh-in-motion (WIM) stations located all over Indiana. Each WIM site has axle sensors, steel pads, and inductive loops permanently embedded in the road surface. The WIM stations collect traffic data all year round and operate through a central control system at INDOT's main office. Data from the WIM stations are downloaded every day using a modem and a standard telephone line. One individual INDOT personnel quickly "scans" the raw data collected from all stations in an attempt to see if there was any severe malfunction with the station (such as missing data). Unfortunately, this is a very inefficient way to check the validity of the data because a WIM out of calibration will still collect a full day's worth of data, and the gradual degradation of the data may not be detected for days or weeks.

Given the complexity and sensitivity of the WIM equipment, it is not surprising that a number of factors affect how the stations function over the course of the year, such as weather, temperature, and the condition of the surrounding pavement. Therefore, a WIM

station can easily become out of calibration, making the data collected invalid. It is of extreme importance that the WIM equipment be monitored over the course of the year for calibration and other malfunctions, with a crew available to fix the station as soon as possible. At the present time, no one at INDOT has the task of continuously monitoring the performance of the stations in the manner described, and INDOT does not have a crew that regularly maintains the WIM stations in optimum performing condition.

C. Evaluation of the existing situation and recommendations

I) Checking the validity of data collected by the WIM equipment

The current practice of glancing over the raw data in an attempt to detect errors in the data is very inefficient and ineffective. A typical day contains an average of 300k worth of data and even the best trained eye cannot detect the subtle anomalies that the data may contain. If the weights collected by the equipment are off by 4 percent, this will translate into a significant difference of about 16 percent after conversion to equivalent single axle loads (ESAL). [Dahlin] Research into this has shown that the best way of checking the validity of the data and the performance of the WIM station is graphically.

There are two ways to check the data collected by the WIM equipment. One is by examining the raw data itself, and the other by looking at the site summary reports. The Minnesota Department of Transportation has worked on how to check the accuracy of the data collected by examining the raw data itself. By plotting the gross weight distribution, front axle weights, and the ESAL factors for the Class 9 vehicles, it is possible to determine whether a WIM station was functioning properly, out of calibration, or if it was malfunctioning. More information regarding this method can be seen in Appendix **. Even though this is a goody to determine the validity of the data, it is very time consuming because you are still dealing with the raw data itself. Another method to check the validity of the data is by producing the daily site summary reports. Using a special software that comes with the WIM station, it is possible to get a site summary report for that station within 5 minutes. The percent error, percent Class 0 vehicles, and the Class 9 Average ESAL / Total Average ESAL were found to be very effective in detecting a WIM malfunction (See Appendix ** for more details). These values could be plotted in order to continuously verify the status of the WIM equipment on a daily basis. Even though this is a quick and easy way to detect a malfunction, it cannot identify the type of malfunction that the WIM is experiencing. Both methods could be used together in the event of a suspected malfunction in order to try and pinpoint the type of malfunction that is present.

II) Calibration of WIM systems

Research has shown that WIM equipment needs to be constantly monitored for calibration over the course of the year. INDOT acknowledges that it does not have a specific program to keep the stations properly maintained all year round, and the

maintenance crew deals only with severe WIM malfunctions or breakdowns. By talking to various State DOTs, it was found that the performance of the WIM stations can vary during the year, depending on the season. As a result, it could mean that a WIM station may need three to four calibrations each year in order to continue to obtain valid data. As for calibration itself, it is important not to rely on a single type of truck for the calibration of WIM systems. Research suggests that the dynamics of any given truck are unique and can be very different from other trucks with the same axle configuration (See Appendix ** for more detail).

Because there are no guidelines set by the FHWA on how to calibrate a WIM system, it was important to gather information from other State DOTs to see how they tackle the problem. The Ohio DOT owns a 5-axle semi-trailer and a 3-axle dump truck both of which are used to calibrate the WIM stations, because these two types of trucks are usually the most dominant vehicles in the traffic stream. (On occasion, ODOT also use a 6-axle tridem). As for the calibration procedure itself, the department uses 3 speeds (usually 35, 45, & 55 m.p.h.) when calibrating the equipment. (If for some reason, e.g. due to the grade of the pavement, the trucks are unable to reach such high speeds, the department calibrates the system using speeds of 25 & 30 m.p.h.). The trucks make three passes, the system is then adjusted accordingly, and 2-3 more passes are made to verify the calibration.

As a result of the findings above, there are several recommendations to be made:

1) Monitoring the performance of the WIM should be of utmost importance. Valuable time and precious data could be saved if the maintenance crew could be sent out to a WIM station as soon as the system is suspected of malfunctioning. Two teams, each trained in detecting WIM data anomalies, should be assigned the task of continuously monitoring the performance of the WIM equipment. An additional team could also be trained and put on a stand-by basis as a precaution against other members being put on temporary assignments, in case of an illness, or when a member is on vacation.

2) Due to the severe weather changes in the State of Indiana, it is recommended that the WIM equipment be calibrated at least twice a year (in the Winter and Summer). It is likely that this will result in fewer and shorter-lived malfunctions and therefore more reliable and accurate data will be collected from these stations.

3) It is recommended that the WIM stations undergo several maintenance checks every year. In order to save time and money, some of these could be done during the re-calibration procedures.

4) Several full-time crews will be needed in order to keep the WIM stations properly maintained and calibrated. The number of crews needed will be a function of the time it takes to perform these procedures. They could also perform other objectives, such as

installing cameras for the Congestion Management System while on their way to the WIM sites.

DRAFT TMS/H Data Action Plan **G**
Database Systems
Samuel Labi, and Jon D. Fricker
September 21, 1998

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INDOT Work Plan Activity : *Verification of adequacy existing database to accommodate additional vehicle data requirements, and investigation of alternate database options and selection/recommendation of new system if appropriate.*

1. DESCRIPTION OF EXISTING DATABASE SYSTEM

The following list shows the hardware and software currently being used at various stages of database management at INDOT Traffic Statistics Division:

- 1 Mainframe computer (IBM 5620), partially used for data manipulation such as re-organization, sorting, and calculations, including estimation of summary statistics and adjustment factors. This computer is currently used only for manipulation of Telemetry and coverage count data, and is not used for processing of weight data.

- International Road Dynamics (IRD) Central Control System, for polling (automatic collection of data directly from field WIM equipment via modem and IRD software.
- 1 personal computer (IBM PC 486), used for polling of raw WIM data, for generation of WIM reports, and for saving of raw data on optical disks.

- Streeter Richardson Telac 560 Central Station, for automatic collection of data from Telemetry field stations.
- 1 personal computer (IBM PC 286, 16 Mhz), for polling of raw Telemetry data
- 1 personal computer (IBM PC Pentium), for data editing and analyses, and report-generation

- 2 personal computers (IBM PC Pentium) for creation of checksheets for selection of coverage count locations, editing of coverage count data, etc.
- 1 personal computer (IBM PC Pentium) for general report generation and supervision of data processing and analysis duties.
- 2 personal computers (IBM PC Pentium) for traffic projection analyses.

- 7 site-based portable IBM personal computers, for coverage count data printing and checking, and copying of data on floppy disks. This equipment uses TDP software, and Microsoft Excel.

- 3 personal computers (IBM PC 286) based at the INDOT Field Office,

for checking of copied data on floppies and printouts for validity.
This equipment uses TDP software, and Microsoft Excel.

- 4 laptop IBM personal computers based at the INDOT Field Office, for field use (checking of data copied on floppies and printouts for validity, etc.)
  This equipment also uses TDP software, and Microsoft Excel.
- 1 personal computer (IBM PC 486), for data review, checksheets compilation and data validation, evaluation and application of excess axle adjustments, and preparation of data for input to mainframe computer, using TDP software, and Microsoft Excel.

A list of hardware and software currently being used at various stages of database management at the various MPOs is provided in Appendix 3b of the main report.

2. REQUIREMENTS OF APPROPRIATE DATA SYSTEM

The development and implementation of a Traffic Monitoring System for each state, which is a federal requirement, translates directly into an increased amount, scope and complexity of traffic data collection, analysis and processing, and reporting needs. Some expected improvements to the data collection activities include upgrading of existing Telemetry stations to carry out vehicle classification counts, establishment of a portable weigh-in-motion program, coverage count monitoring (volume and classification) on all NHS roads on a two year cycle, adoption of increased monitoring frequency for higher growth counties, and performance of non-traditional measurements of traffic characteristics using non-intrusive equipment. With these planned expansions, it is envisaged that about 60MB of data will reaching the INDOT Head Office on a *daily* basis for analysis and processing. The current staff strength is too low to meet this demand, and present system of data handling is severely limited in its capabilities and is not expected to be able to cope with the large volume of traffic data that would result from the implementation of such future developments.

A. Hardware for Data Management

A.1 Physical architecture

According to the *Traffic Monitoring Guide* (TMG), p. 3-2-11, the management and analysis of traffic data require the use of computers, and a fully computerized operation would allow early preparation of reports and reduce any existing information lag.

The TMG suggests that hardware for the traffic data management portion of a Traffic Monitoring System should, as a minimum, generally consist of:

1) A mainframe computer, and
2) an appropriate number of microcomputers operating independently but capable of being linked to the mainframe.

According to the TMG, the advantages offered by large mainframe computers include high speed and large capacity, but effective and full utilization of such computers are usually hampered by relatively high operating/maintenance expense and lack of user

control. With the advent of very powerful microcomputers with high processing speeds, the cost effectiveness of microcomputers has greatly increased, and such computers should be procured to handle specific tasks which would be relatively inefficient for the mainframe to perform.

A typical hardware system architecture may consist of more than the two components that have been described above. In addition to PCs and mainframes, mid-range computers (i.e., servers) and workstations may be added to the hardware system to facilitate data management.

The PCs currently in use at INDOT for analysis and processing of traffic data cannot be expected to handle the enormous amounts of traffic data that would need to be processed after the implementation of the proposed changes to the data collection activities of the traffic monitoring system. An assessment of the current inventory of usable computers in the Traffic Statistics Section, vis-a-vis the increased scope in data management that is expected after implementation of the recommendations of this study, has been made. As a result of this assessment, the procurement of the following additional hardware, as a minimum measure, is recommended:

- 1 mid-range computer, such as IBM 704
- 1 work station such as IBM Intel. Station M. Pro-689814U
- 3 personal computers, such as IBM PC 350.

The *Traffic Monitoring Guide* further suggests that the system architecture and networking environment should be such that it should be possible to transfer files directly between the microcomputers and the mainframe computer. Such transferability, according to the Guide, would allow the analyst to perform analysis, processing or report generation on the computer type that the analyst deems most cost effective for the given task, be it micro or mainframe. Another desirable feature of the hardware component of a good database system is that it should permit connection not only to all networks within various sections of INDOT's Traffic Statistics Section, but also to all networks within the various divisions of INDOT. Further, the network environment should enable connections across regular phone lines.

As has been done for the Albuquerque Traffic Monitoring System (ref. *The Albuquerque Traffic Monitoring Program*, by Blewett, Lewis & Day), INDOT's network environment should enable automatic linkages between the summary statistic files in the database system, a Geographic Information System, the state's Road Inventory File, and the state's Linear Referencing System, so that traffic data could be effectively linked with the environment and software desired at any particular time.

A.2 Retention Media for Traffic Data

According to the *AASHTO Guidelines for Traffic Data Programs*, the most common forms of long-term data storage are low-cost technologies such paper reports, microfiche,

and microfilm. Microfiche and film have an advantage over paper reports in that they need very little space and are less vulnerable to environmental conditions. However these technologies, according to the *AASHTO Guidelines*, cannot efficiently store large quantities of data, and make retrieval of large data-sets rather cumbersome. The Guidelines encourage state agencies to consider the use of computer-based optical storage.
The AASHTO Guidelines offer the following data retention periods for the various count types:

Count Type	Retention Period
Permanent Counts	10 years to permanent
Short-term Counts	10 years
Research databases	10 years to permanent
Summary Statistics	10 years to permanent

In this context, the *AASHTO Guidelines* define permanent counts as those that are taken at selected locations on a continuing or routine basis. According to this definition, HPMS counts are considered as permanent counts within the context of data retention. The Guidelines state that permanent count data should be retained for a relatively long period of time because they provide historical trend information, and trends need to be studied over fairly long periods in order to be useful.

Short-term counts, in this context, are defined as counts for which data are not collected at the same location on a routine basis. Because such counts do not correspond to other counts at the same locations, these data are not considered very important from a historical perspective, and may therefore be kept for a minimum of only 10 years.

Research databases include all traffic data that are collected specifically for research purposes. The Guidelines recommend that traffic data that play a critical role in research that influences the design, operation or maintenance of highways should be retained permanently so that the conclusions reached and recorded by the researchers can be reviewed and validated at a later date. Traffic data that do not have such influence may be stored for a minimum of 10 years.

By the term "summary statistics", the *AASHTO Guidelines* refer to summary data calculated from available data-sets that are used in an analytical processes (such as a pavement management system or a statewide accident rate analysis process) or are used to describe the functioning of some aspect of the highway system. Statistics and reports serve a variety of uses and have different levels of significance. The Guidelines recommends that " Computer files used by analytical procedures should be retained for 10 years and then discarded ...[and] printed reports and summary values of significance

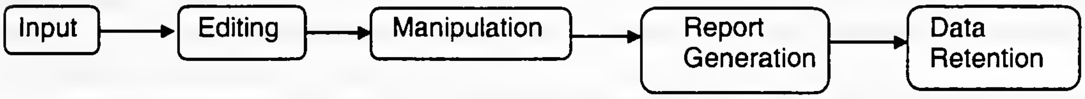
to the agency (for example VMT statistics by jurisdiction used for fund disbursement or traffic flow maps) should be retained permanently to maintain a historical record of traffic activity."

In the current situation, INDOT stores its traffic data on optical disks that have 500MB on each side. One month's data takes approximately 350MB. Most MPOs in the state of Indiana retain their traffic data in spreadsheet format on computer hard drives, floppy disks, and on hard copy print-outs that are published on a regular basis. The Madison County Council of Governments (MCCOG) has gone a step further to store its traffic data on electronic maps using TransCAD and AutoCAD software.

The data retention aspect of the State of Idaho's traffic monitoring system is such that all raw data collected during a monitoring session, as well as information on the dates and hours of monitoring, remain available until the traffic or travel estimates based on the count sessions are updated. However, the duration of retention of summarized data for that state is not yet known. New York State DOT retains 15 years of data at the aggregate level in an active file on a mainframe computer. Detailed short-term counts and aggregate data older than 15 years are retained on back-up devices, and that state currently has no plans to delete any data.

B. Software for Data Management

Stages of Data Management



The above figure shows the sequence through which traffic data passes from the starting point (input) to the endpoint (data storage). A good database system should address the appropriate processing needs of traffic data at each stage of the entire process.

B.1- General requirements of database system:
The database system should ...

- have a demonstrated ability to handle traffic data. The successful experience of the Federal Highway Administration (FHWA) or other state departments of transportation with a particular database system makes that system a likely candidate for selection.
- be able to generate traffic data statistics and reports in the form and formats required by the FHWA and HPMS Field Manual, for the ATR and HPMS coverage count programs, and by the LTPP.
- comply with editing, analysis, and reporting procedures spelled out in the *Traffic Monitoring Guide* and *AASHTO Guidelines for Traffic Data Programs.*

B.2- Specific requirements of database system:

B.2.1. **Input/data access capabilities** required of database system:
INDOT already has in place an advanced field data collection system for permanent counts consisting of automatic traffic recorders that communicate collected data through regular phone lines and modems to the INDOT central office. The database system should be capable of receiving such data directly from the field stations. Also, the database system should be able to store all the data files in their original polled formats for possible future reference.

B.2.2. **Editing capabilities** required of database system:
INDOT's current data collection activities are associated with a significant number of problems: field equipment is subject to occasional malfunction and disturbance from external factors such as road construction. Because of such problems, raw data from some sites are either missing or incorrect. It is very important that erroneous data be identified and excluded from analysis. To a great extent, personal judgment is required for this exercise, because data that may seem to be erroneous may not be due to equipment malfunction, but could rather have been caused by road closures, special events, or other atypical traffic conditions. However, the database system should be able to assist in the editing process by flagging suspicious data quickly and efficiently for review by the analyst. This may be done in two ways: a) direct flagging of data while it is in a tabular form, b) linking the database files to a GIS to enable editing of data in a spatial context. Further details on the editing process are provided in Data Action Plan H1/H2 (Short-term counts- Procedures used in data processing and analysis).

B.2.3. **Manipulation (analysis/processing) capabilities** required of database system:
The database system should generally be capable of performing the necessary computations to arrive at the required site-specific and system-level statistics and adjustment factors, such as AADT, VDT, and traffic volume adjustment factors for the various traffic volume seasonal groups.
Specifically, the database system, according to INDOT's contact person for this data action plan, should be capable of analyzing traffic data to produce the following summary statistics on a daily, monthly and annual basis:

Daily: daily error logs, continuous count volume and weight summaries, short-term count summaries of all three count types, and vehicle % 'F' table for collected data by lane.

Monthly: Volume summaries by vehicle type, binned data by lane for vehicle type, speed, etc., average flexible ESAL and rigid ESAL distributions by lane, average gross vehicle weights by lane, average hourly traffic at continuous count stations, consolidation of coverage count data by county, and by functional class.

Annual: Seasonal adjustment factors, by user-definable road type grouping, and by user-definable volume grouping, seasonal adjustment factors by day of week, weekday,

and weekend, growth factors by user-definable road type grouping, and by user-definable volume grouping, growth factors by day of week, weekday, and weekend, growth factors, user definable percentiles by volume, and class with date and time from permanent count system, annual ADTs and AADTs by station.

The database system, according to the contact person for this data action plan, should be capable of validating an average ADT of 3.5 million vehicles with a commercial vehicle component of about 15%.

B.2.4. **Report generation capabilities** required of database system

B.2.4.1 General reporting capabilities:

- Structure should meet the needs of the end users of the traffic data
- Should be capable of producing graphic representations of traffic data (see details in Section 4.1).
- Should, in accordance with the principle of Truth-in-Data, indicate the quality and quantity of data supporting traffic statistics on a site-by-site basis, as explained in the *AASHTO Guidelines for Traffic Data Programs*, p. 71.
- Should be flexible enough for customization, so that desired program capabilities beyond the original capabilities may be developed to meet any special needs regarding data manipulation and reporting. According to the *Traffic Monitoring Guide* (TMG), "Software needs beyond the available packages can be developed through the use of language compilers, or through contracts with the appropriate sources." The TMG cautions however that in view of the costs, required skills and problems associated with software development, it is more efficient to procure, as much as possible, software that is already capable of performing all, or most of the desired functions.
- Should be able to link files of various count sub-programs and programs (Telemetry, Weigh-in-motion, Coverage, etc.), so that data from one sub-program or program may be accessible to another. For example, the file for volume counts carried out by the WIM sub-program should be easily accessible from the file for volume counts carried out by the Telemetry sub-program. Also the file with classification counts carried out by WIM stations that happen to be on HPMS sections should be accessible to the file for HPMS classification counts.
- Should be able to report traffic data in the format recommended by the FHWA. Because traffic data are shared with other state agencies and transmitted to federal agencies, it is imperative that such reports are consistent with recommended formats, so that the information they present can be clearly understood and appropriately used. According to the *AASHTO Guidelines for Traffic Data Programs*, traffic reports should have consistent terminology and labeling. These guidelines also state that the same format should be used in all electronic transmittals of traffic data.

The *AASHTO Guidelines* provides formats for electronic reporting of each of the three traffic data types.

B.2.4.2 Specific reporting capabilities:
The database system should be able to generate daily, monthly and annual reports for summary statistics as has been described in section B.2.3 of this document.

B.2.4. **Data Retention capabilities** required of database system:

The database system should consist of appropriate types of hardware and software that would make it possible for data to be stored efficiently for the desired retention period, as discussed in the "Hardware" section of this document. The INDOT contact person for this data action plan states that any new database system should possess sufficient redundancy in storage and processing capacity to allow for a possible 5% growth rate in traffic volumes for the following ten years.

B.2.5 **Other** required capabilities of database system

B.2.5.1 **Data visualization and graphic representation** of traffic data:
Visual presentation of multi-dimensional data is vital in the traffic data management for two reasons: (i) relationships among several data values need to be explored in a quick and efficient manner, (ii) the source data is voluminous and is usually available in a structure that does not permit easy and quick examination of trends across various dimensions. Visualization tools are therefore necessary to help the user reveal information that often goes unnoticed in the textual and tabular forms. The database system should be such that graphical models can be created analyzed and modified.

Specifically, the system should be able to generate graphic reports of traffic data and trends in traffic characteristics. There are two main requirements for this:

a) The database system should be compatible with a Geographical Information System (GIS) so that the files in the database system can be processed by the GIS software for geographic presentation of the traffic data.

b) The database system should be capable of directly producing two- or three-dimensional graphic representation of traffic data and traffic trends. Such graphics should be able to show, but not be limited to, the following:
   - (i) diurnal distribution, i.e., variation of a traffic characteristic (e.g., volume) per hour or per a selected interval such as 15 minutes, for a total period of 24 hours.
   - (ii) distribution of daily traffic characteristics over a week or month or other selected interval
   - (iii) variation of hourly, daily or weekly traffic characteristics for the various seasonal groups of functional classes of road.
   - (iv) interaction between one distribution and another, e.g., monthly patterns and day-of-week pattern.

The *AASHTO Guidelines* state that: diurnal distributions may be site-specific or they can be aggregate; that the distributions may be reports of specific short-term counts, or they may be data from ATR sites. The Guidelines further state that the distributions can be based on monthly or annual statistics.

On page 66 of the Guidelines, it is stated that diurnal distributions provide users with information about changes in traffic demand or characteristics, and these reports may be used in determining optimal hours for lane closures for maintenance or construction activities. The information is sometimes used in responding to public or private sector interest in land use impact analyses.

The *AASHTO Guidelines* also suggest that the diurnal distribution can be combined with trip generation factors to anticipate traffic impacts of proposed changes in land use. Graphic representation of the seasonal factors, according to the Guidelines, provides a clear picture of the month-to-month differences in travel characteristics related to seasonal causes. Also, the day-to-day pattern of variation within the week shows how differences in travel behavior are related to day of the week.

The various ways in which traffic data may be viewed in a GIS medium, and their possible uses, are explained in Section D of this data action plan.

B.2.5.2 **Linkage** capabilities of database system to other database systems:
The database system should have an interface that should be capable of linking the system to other relational database management systems such as ORACLE, PC file formats, and the format currently available on INDOT's traffic data collection devices. This would ensure access to all information sources currently in use at INDOT, and would also enable connectivity within the INDOT traffic data system, i.e., the ability to share data and applications across users, terminals, or work functional areas.

B.2.5.3 **Friendliness and versatility** of user interface
The user interface should be easy to comprehend, and should be of such wide range that different levels of user skills can be accommodated.

B.2.5.4 **Independence** of database system from hardware
The software associated with the database system should be compatible with all platforms currently being used at INDOT, and with any platform that may be acquired in the near future, including PCs, workstations, and mainframes.

B.2.5.5 **Minimum disruption** to current operations of INDOT's Traffic Statistics Section. It is essential that the structure and overall features of the new database system should be such that implementation of this new system would be accompanied by minimal disruption to the activities of INDOT's Traffic Statistics Section. It is desirable that the new database is installed within a short time, and with as few changes to established data collection procedures as possible.

B.2.5.6 **Warranty and support** on a continuous basis
According to INDOT's contact person for this data action plan, the following aspects of warranty and support are required of an appropriate database system to be used for the management of traffic data:

- Reasonably short response times to service requests
- Unlimited phone support during business hours regarding software and hardware issues
- Technical support, development, additional training and consulting

C. EVALUATION OF ALTERNATIVE DATABASE SYSTEMS
Two alternative database systems were proposed and evaluated, namely the Traffic Data System Version 2 (TRADAS 2) supplied by Chaparral Systems Corporation, and the Statistical Analysis Software (SAS) system supplied by the SAS Institute.

C.1 The TRADAS 2 System
The TRADAS System is a database system specifically designed for the analysis, validation, reporting, storage, and management of traffic data in the forms and formats required by the *Traffic Monitoring Guide* of the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) *Guidelines for Traffic Data Programs.*
The main functions of the TRADAS system are two-fold: Data Processing, and Data Dissemination.
Data processing. TRADAS enables the performance of quality control and quality assurance on collected traffic data. This includes editing of traffic data. Also, TRADAS provides a means for data storage, access and retrieval.
Data dissemination. TRADAS makes it possible for the generation of traffic data reporting using standard forms as well as agency specific formats. Using TRADAS, the user is able to link tabular and geographic databases. An interface also exists for the user to link other software and database systems.

According to its vendors, some features of the TRADAS system include:
(i) Compatibility with non-traditional sources. Data from sources such as magnetic imaging devices, infrared cameras, and microwave systems can be handled by TRADAS after requisite customization of the system.
(ii) Data from diverse sources. The TRADAS system handles archived data in various vendor formats, and data from the various count programs (coverage and continuous counts, special turning movement counts, etc.) and various count types (weigh-in-motion, telemetry volume and classification counts).
(iii) Quality control. TRADAS makes it possible for the user to carry out quality control checks on collected data and flagging of suspicious data. The quality control system within TRADAS has both standard checks and checks that permit user input of checking parameters. The vendor of TRADAS (Chaparral Systems Corporation) is engaged in a research program for quality control of traffic data, through its Traffic

Technical Assistance Contract for the FHWA's Long Term Pavement Performance (LTPP) project.

(iv) TRADAS maintains a public Oracle database that can be assessed through the TRADAS clients, through Oracle tools, or through external access procedures such as ODBC. All TRADAS data are capable of being exported using the standard oracle tools.

(v) TRADAS offers, as an option, a World-Wide Web interface to the public database. According to the vendors, INDOT will have full control over the extent and timing of the availability of the public database.

(vi) In TRADAS, several graphical display mechanisms are available, such as

- standard graphical reports prepared using the Oracle Developer 2000 system
- graphical displays for quality control in the user interface
- ODBC-enabled applications such as Microsoft Excel.

(vii) User friendliness. The TRADAS 2 interface is a Windows 95-style graphical user interface that, according to the vendor, is intuitive and easy to learn.

(viii) Data access and retrieval. TRADAS provides multiple access and security levels based on roles and privileges. All data, even the archived data, are available using the TRADAS system.

(ix) Reporting capabilities. The TRADAS vendors state that this database system has the following features:

- Correctly formatted FHWA and LTPP detailed reports
- Traffic data elements for HPMS submission requirements, computed using the "best available data" philosophy
- Computes peak hour statistics by day for each direction and for the roadway , for both morning and afternoon peak periods. Also computes peak hour factors for sites having 15-minute data collection intervals
- Prepares the following daily reports: daily error logs, continuous count daily summaries, coverage count daily summaries, etc.
- Prepares the following monthly reports: monthly volume summaries by vehicle type, monthly binned data by lane for vehicle type, speed, etc., monthly average rigid and flexible ESAL distribution by lane, monthly average gross vehicle weights by lane, monthly average hourly traffic at continuous count stations. According to the vendors, consolidation of coverage count data by county and functional classification is possible using TRADAS, but this would require a minor customization task.
- Computes the following adjustment factors: seasonal adjustment factors by user-definable road type grouping and by user-definable volume grouping, seasonal factors by day of week, weekday, and weekend, growth factors by user-definable road type grouping and by user-definable volume grouping, growth factors by day of week, weekday, and weekend, axle adjustment factors by user-definable volume groups
- Estimates Average Daily Traffic(ADT), Annual Average Daily Traffic (AADT)

Cost, technical support and training for the TRADAS system:

The overall cost of the TRADAS database software package is $205,000. This includes 160 hours of technical support, development, training, consulting and 1 year warranty. Only basic user training is covered under this price quotation. Intermediate and advanced user training are offered as optional items and are priced at $1300 and $5600, respectively. Hardware support is provided on site, while software problems are addressed remotely through the TRADAS customer support system. However, in cases where the problem cannot be solved remotely, the vendors dispatch a software support technician to the client within 48 hours. Further, the vendor guarantees a maximum of 1 hour response time and unlimited support via telephone. The cost of extra technical support and warranty are considered as optional items, and are therefore not covered in the main cost of the database system.

The TRADAS system is currently being used for traffic data management at the Departments of Transportation of several states. According to Mr. Ralph Gillman of the FHWA, about 12 states have formed a TRADAS user group. These states include Missouri, Idaho, Virginia, New Mexico, and Delaware. According to the DOT of the state of Idaho, complete installation of TRADAS will facilitate management of traffic data, development of adjustment factors, and receipt of data from the local counties, cities and MPOs for processing, reporting and storage. In the current situation at Idaho DOT, most ATR and short-term counts are processed through the TRADAS software, while weigh-in-motion data is processed on PCs using SAS programs that were developed in-house.

C.2 The SAS system

The SAS system is an integrated suite of software for information delivery, designed and marketed by the SAS Institute of Cary, North Carolina. The functionality of the SAS system is built around four data-driven tasks, namely, data access, data management, data analysis, and data presentation.

In the February 1996 issue of *Datamation*, a prominent magazine that monitors trends in information systems, the SAS system was featured as having been awarded the overall winner in the data warehousing category of the top new products for that year.

One of the special features of SAS is the Online Analytical Processing (OLAP) technology, which makes it possible for the user to view data from multiple dimensions or areas of interest, and enables a closer examination of data from a variety of angles that reflect the user's concerns. According to a SAS Institute white paper entitled "A Formula for OLAP Success", the major difference between OLAP and other types of tools are that OLAP offers the capability for modeling multidimensional scenarios to represent the real world and the ability to move from one view to another by changing dimensions. An example of a dimension within data is a specific time frame for which the data are being viewed.

In another SAS Institute white paper entitled "Rapid Warehousing Methodology", OLAP is said to offer summarization at all levels of aggregation, and therefore makes it possible

for users to carry out queries and explorations without necessarily knowing about the organization of the underlying data. This feature, according to the paper, enables the user to slice through layers of data, in multiple directions, to easily uncover values of interest.

The white paper also highlights other capabilities of the SAS system as follows:

(i) Accessing data: The SAS data warehouse system has access methods available that optimize extraction of data regardless of the form of operational data. According to the paper, the enabling technology behind the data access strategy, named Multiple Engine Architecture, provides access to more than 50 different types of relational, hierarchical, and network database management systems, and other systems. The SAS business catalogue titled *The SAS System for Information Delivery* states that "A transparent, consistent and reliable interface links the SAS System with relational database management systems such as DB2, ORACLE, SYBASE, INFORMIX, INGRES, and DEC Rdb ... hierarchical files such as IMS ... legacy files such as VSAM... data gateways such as ODBC ... operating system files ... popular PC file formats such as DIF, DBF, and WKx ... real-time data collection devices ... and SAS data files."

(ii) Integrating and transforming data: The SAS system is capable of the following tasks:

- Data integration: access methods and consolidation tools for combining different data entities from different sources.
- Data validation: procedures for screening of data sources in order to identify potentially invalid or inconsistent data
- Data mining: identifying trends and relationships within data in order to highlight inconsistencies or exceptions.

(iii) Querying and Reporting of data: The SAS system provides tools for ad-hoc query and reporting and batch reporting of information in the data warehouse. The menu-driven interface, according to the paper, can be tailored to fit the requirements of the user. Querying tools include a native sequential query language (SQL) dialogue.

(iv) Decision support and visualization: Software within the SAS system enables high-level analysis of data in the data warehouse to support decision makers through modeling, forecasting, visualization, simulation, etc. According to the paper, solutions can be developed based on a wide range of techniques such as statistical analysis, econometric methods, and geographical information systems.

(v) Compatibility with the internet/intranet: The white paper states that the OLAP server is accessible from any web browser, and with this technology, organizations can enable access to the OLAP server by merely adding a Web address to the network and making simple changes to security where needed.

(vi) Report preparation: The SAS system has an interactive report writing tool that can be used for quick formatting and customizing of reports.

Cost of package, technical support and training for the SAS system:
From telephone conversations with the SAS representative (August 1996), the cost of the SAS package is $30,000 per annum. According to the *SAS System for Information Delivery*, SAS Institute provides free technical support -- via phone, mail, or electronic media -- as part of the acquired software license. This document also states that a comprehensive training curriculum is available for SAS System users, and that this training is tailored to the needs of the client. Various formats of training offered by the SAS Institute include instructor-based courses, trainer's kits, on-line training, and video-based courses and tutorials.

On December 18, 1995, representatives of the SAS Institute carried out a presentation to an audience consisting of personnel of the Traffic Statistics Division of INDOT and researchers from Purdue University. This presentation focused on the capabilities of the SAS software in handling traffic data, and special features of the SAS system such as its data warehousing concept, applications development, and possibility of integration with a geographical information system.

The SAS system is currently being used for traffic data inventory systems at the Departments of Transportation of three states: Iowa, Illinois and Wisconsin. Also, SAS is currently being used for some data management functions on the mainframe computer and VAX system at the Traffic Statistics Section of INDOT's Roadway Management Division. At the State of New York DOT, ATR data is analyzed on an IBM mainframe computer using primarily the COBOL programming language and SAS programs.

C.3 Conclusions, and selection of better system:

As was revealed at the December 18, 1995 SAS presentation, INDOT already holds licenses to use SAS. Thus it is expected that the use of SAS would involve saving of some extra expenditures. However, SAS is a very general package, and it is envisaged that use of the SAS system would be associated with a tremendous amount of customization to suit the needs of INDOT. This would be expensive in terms of cost and time. The TRADAS system is already tailored to suit the requirements of state DOTs, the FHWA, and AASHTO. One disadvantage with the TRADAS system is that its installation and initial costs are expected to be more expensive than that of SAS. Any modifications to TRADAS must be done by New Mexico-based Chapparral Corporation, while SAS has a representative in Indianapolis. Annual operating costs of using TRADAS, however, are expected to be far lower than that of SAS.

Furthermore, TRADAS has been adopted for use by departments of transportation in over 12 states. Such states have formed a user group to share ideas and exchange experiences. SAS does not have such a demonstrated history of performance with state DOTs.

In conclusion, TRADAS appears to superior to SAS, from both technical and financial perspectives. It is therefore recommended that TRADAS 2 be purchased for management

of traffic data to meet the current and future needs of the traffic statistics section of INDOT's Roadway Management Division.

D. INTRODUCTION OF NEW TECHNOLOGY FOR REPORTING & EDITING PURPOSES:

Geographical Information Systems (GIS), which offer much promise and potential in the management of traffic data, are generally described as a collection of hardware, software and data systems for collecting, storing, analyzing, and disseminating information about areas of the Earth.
An entire database for summarized traffic data can be built and stored using a GIS. Most GIS software offer the capability to retrieve and review data quickly and efficiently in a map form. Such retrieval operations, called queries, are associated with a set of menus that would allow the user to view the entire traffic monitoring system through pre-defined themes or coverages. For instance, a theme showing the counties in the state of Indiana may be overlapped with another theme showing the NHS network. Suggested themes that can be used are provided after this chapter.

The underlying design of any GIS is such that each theme consists of a set of one or more "primitive features" such as polygons (e.g., counties, regions, districts), arcs (e.g., streets, railways, highways), and nodes (e.g., bridges, intersections, count sites). Pointing and clicking at any feature can obtain the attributes of that feature. These attributes, for a Traffic Monitoring System's GIS, could include traffic volumes, classification, truck weights, date of count, and factors. For example, the user may obtain the traffic volume and percentage trucks at a bridge site. Attributes may also include traffic-related spatial characteristics such as population density, road length, pavement type, etc.

If further detail is needed, the user may simply use the zoom feature for a closer view.

The GIS may be designed to yield the most recent traffic data by default upon request. However it may be flexible enough to allow the user to select the year for which the data are desired, and to determine which locations are scheduled for traffic data collection at a specified future date.

Printouts of any combination of overlapping themes can be obtained in color with a simple command. A GIS for INDOT's traffic monitoring system would function as a universal traffic data warehouse within a geographical context. It would make it possible to view relationships not only between traffic attributes, but also between traffic attributes and non-traffic spatial characteristics, e.g., land use. Furthermore, a GIS system enables performance of various analyses on the spatial data. Such analysis include buffering (selecting/highlighting all points within a specified distance from a given point or line) and shortest path analyses.

Data retrieval procedures inherent with most GIS are considered superior to those of other database systems. Relatively little time is required to perform routine tasks in a GIS system, and large databases are handled very easily and quickly. Also, with a GIS, unlike other conventional database systems, the entire universe of locations for given theme can be viewed on one screen.

Another advantage of GIS is that errors associated with unfamiliarity or lack of knowledge of the database are obviated. Querying operations in most non-GIS systems start by typing in the name of other identification attributes of the feature under query. In such environments, there is uncertainty about whether the needed data has been fully AND correctly retrieved due to possible problems such as errors associated with the data (e.g., misspelled attribute names) and lack of knowledge about the universe. For example, most state roads in Marion County have relatively high traffic volumes. A non-GIS database user who queries volumes on one of these roads may not recognize that any query response yielding a very low traffic volume may reflect erroneous data, because the user may not be personally familiar with actual traffic conditions on that road. However, a GIS-database user need not be familiar with the road to spot the obvious error, because from the spatial graphics on the screen he may realize that a state road in this urban area is likely to have relatively high volumes.

On a periodic basis, summary files from the various count elements should be imported by the GIS analyst to update the database. At the initial stages of setting up a GIS for INDOT's traffic monitoring system, only summarized data need to be stored and reported, but eventually, the system would be developed to store raw counts as well.

It is further suggested that all end-users of the traffic data be linked by a local area network (LAN/WAN) to the GIS database so that they may easily retrieve needed information without recourse to administrative procedures. Such a database would need to be protected from unauthorized modification of data by putting in place necessary network security measures. The database system could be linked such that internet and intranet (in-house INDOT users) may access various information of interest to them.

Currently, the linear referencing system has been designed for only the state roads. This should be extended to the local roads, so that requisite data on the local road system may be managed in the appropriate format.

Suggested themes for INDOT's GIS system are:
- Counties
- Degree of urbanization of areas, i.e., rural, urban, or small urban
- Entire statewide road network, showing functional classification
- HPMS universe sections, showing functional classification
- HPMS sample sections, showing functional classification
- National Highway System, showing functional classification
- Cities, towns, farms, forest reserves
- Recreational areas

- Intersections and interchanges
- Congested sections
- Locations with high crash rates
- Movement of commercial vehicles (truck flow maps)
- WIM data collection points
- Telemetry data collection points
- Coverage count data collection points
- Intermodal facility locations and access links.

On page I-3 of the *HPMS Field Manual*, under the section titled "Overview of HPMS Reporting Requirements, it is stated that: " the HPMS requires the reporting of area-wide data, universe data, standard sample data, and HPMS linear referencing system data for geographical information systems [GIS]." For HPMS purposes, the HPMS Field Manual defines a GIS as "... a highway network (spatial data which graphically represents the geometry of the highways) and its geographically referenced component attributes (HPMS section data ... and other data ...) that are integrated through a GIS technology to perform analysis".

FHWA Docket N°. 97-10 issued by the FHWA of the US DOT and published in the December 23, 1996 issue of the *Federal Register* (vol. 61 N°. 247) provides an indication of a possible strategic reassessment of the HPMS, the purpose of which is to review the HPMS in light of contemporary issues and anticipated future needs, and to determine what changes, if any, are necessary at this time. According to the notice, "... such contemporary issues and future needs include changing technology such as Intelligent Transportation Systems (ITS), Geographical Information Systems (GIS)...".

To date, the Madison County Council of Governments (MCCOG) is one of the very few MPOs in the State of Indiana so far to store its data in the form of electronic maps using TransCAD and AutoCAD. Other MPOs should be encouraged to follow this example. The choice of a particular GIS software by MPO may be left open to them, but it should be ensured that GIS software used by any MPO should be compatible with that which will be used in the INDOT Head Office.

The following work activities would be involved in the development of a GIS database for INDOT's traffic monitoring system :

1. Development of a GIS action plan
2. Facilitation / coordination of involvement of management systems, MPOs and other end-users of traffic data
3. Performance of a pilot project
4. Implementing the GIS for the Traffic Monitoring System

Development of a GIS Action Plan

The GIS action plan should address some or all of the following areas :

- Review of the existing GIS-related conditions.
- Structuring of the GIS organization
- Establishment of GIS data standards
- Definition of GIS hardware, software, and network requirements
- Identification and definition of applications
- Development of data maintenance plan
- Identification of needed GIS training for management system operators and other end-users of traffic data

Facilitation / Coordination of involvement of management systems and other end-users

This work activity may include :

- Conducting interviews of key personnel in management systems to identify GIS organizational issues
- Providing guidance about ways to prevent or resolve GIS-related problems from the perspective of the end-users

Performance of a Pilot Project

A pilot GIS project for a small area with a dense network, e.g., the Lafayette area, or a large area with a sparse network, e.g., the statewide NHS, should be designed and executed. This should be done in order to achieve the following objectives :

- Test the process and refine standards
- Evaluate GIS applications

Implementing the GIS

This would include the following:

- Inviting GIS vendors to submit proposals for supply of GIS-related software and hardware, evaluating submitted tenders, and awarding contracts to selected bidder.
- Carrying out startup activities for the GIS
- Resolving technical and procedural issues related to GIS implementation

E. ADDITIONAL STAFF FOR DATABASE AND GIS SYSTEMS

D.1 Data Analyst

In view of the increased scope of data analysis expected after implementing the Traffic Monitoring System for the state, and with the installation of a new database system and improved hardware architecture, it is necessary for INDOT to procure the services of a traffic data analyst. The main responsibility of the traffic data analyst would be to carry out the entire range of data management, from receipt of field data to data storage.

The preferred educational qualification of the data analyst is a bachelor's degree in computer programming, database management, statistics, or transportation. However, a lower educational level may be acceptable if it is accompanied by a relatively long period of requisite experience.

The data analyst should have some experience in management of databases, preferably traffic databases. Experience with relational databases such as ORACLE would be advantageous, and proficiency with an established database systems such as SAS-based databases or TRADAS should be a requirement. The data analyst should have a working knowledge of database administration including manipulation of data structures, data mining, sequential query language (SQL), computer programming, and the use of query tools.

Furthermore, the data analyst should also have a knowledge of traffic data analysis procedures in FHWA's *Traffic Monitoring Guide*, AASHTO's *Guidelines for Traffic Data Programs*, and the *HPMS Field Manual*. Prior experience in analysis of traffic data, either in INDOT's Traffic Statistics Unit, or in another state's department of transportation, would be preferred.

A wage survey on the Internet has shown that data analysts with such educational qualifications and experience in database management earn salaries in the range of $35,000 - $60,000 per annum.

This position may be filled independently, or may be part of a larger equipment/staff proposal package offered by a prospective bidder.

D.2 GIS Specialist

The development of a geographical information system (GIS) to assist in the management of INDOT's traffic data should be accompanied by hiring the services of a GIS specialist. The primary responsibility of the GIS specialist would be to create, develop, and maintain a comprehensive database for summarized traffic data using a GIS software. This would make it possible for staff of all levels to retrieve and review data quickly and efficiently in a map form. The GIS specialist could also assist in the editing of traffic data from a spatial context.

The GIS specialist should have a degree in surveying, transportation, or any related field, and should have some experience in creation and/or updating of GIS databases. Proficiency in GIS-related software such as ArcInfo, Arcview, AML/C/C++ programming and AutoCAD would be desirable.

A wage survey on the Internet has shown that GIS specialists with such educational qualifications and with about 2 years experience earn annual salaries in the range of $32,000 - $ 60,000.

E. DETAILS (INCLUDING PRICES) OF REQUIRED HARDWARE AND ACCESSORIES, FOR DATABASE SYSTEM

The following lists show some specification guidelines for computer hardware needed for INDOT's traffic database management system.

1. Server hardware platform operating system (IBM 740 Model 86506 mm or similar machine) with the folowing specifications:

- Dual 200 MHz Pentium II Processors
- 256 MB RAM
- 24X CD ROM
- 3.5 inch Disk Drive
- 4MM DAT, 16GB internal drive
- SCSI-2 Controller
- Two 24 GB RAID5 drives
- Token ring LANSTREAMER card
- External 33.6+ modem
- Windows NT 4.0 server
- 15 inch color monitor
- 3-year manufacturer's on-site warranty
- UPS power supply

2. NT workstation (e.g., IBM Intel. Station Z.Pro-689814U) with the following specifications and accessories:

- 200 MHz Pentium II Processor
- 64MB RAM
- 24X CD ROM
- 2 x 2.5 GB hard drives
- 12 x WORM drive
- Full duplex sound card
- Video card with 4MB EDO RAM
- Token Ring Card
- 21 inch color monitor
- Windows NT
- 3-year manufacturer's on-site warranty

3. Client PC (e.g. IBM PC350) with the following specifications and accessories:

- 166 MHz Pentium ii Processor (MMX)
- 32MB RAM
- 24X CD ROM

- 2.5 GB hard drives
- 8 x WORM drive
- Full duplex sound card
- Video card with 2MB EDO RAM
- Token Ring Card
- 17 inch color monitor
- Windows NT
- 3-year manufacturer's on-site warranty

DRAFT TMS/H Data Action Plan **H1 & H2**

Short-term Coverage Counts II- Data Collection and Analysis Processes & Procedures

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September 21, 1997.

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INDOT Work Plan Activity: Validation and Documentation of Existing Short Term Traffic Data Collection/Analysis Processes and Procedures Utilized in Office Factoring Adjustments.

23 CFR Chapter 1, Subchapter F (Transportation and Infrastructure Management) Part 500 (Management and Monitoring Systems), Subpart H (Traffic Monitoring System For Highways), Section 500.807(c) on p. 63484 of the *Federal Register*, 1 December 1993 states: "Within each state there shall be sufficient counters to provide for ..... the development of day-of-week, seasonal, axle correction, and growth factors or other comparable factors approved by FHWA..."

Part (d) of this section states: "Count data for traffic volumes in the field shall be adjusted to reflect annual average conditions. The estimation of annual average traffic will be through the appropriate application of only the following: seasonal factors, day-of-week factors, and when necessary, axle correction and growth factors..."

With the acceptance of the Interim Final Rule *(Federal Register*, 19 December 1996) numbering of the above-quoted sections have been changed as follows: Section 500.807 is now 500.204.

INDOT'S SHORT-TERM TRAFFIC MONITORING PROGRAM

There are currently three categories of short-term counts being carried out by INDOT:

- Coverage (CFM) counts- This count program involves 48-hour monitoring for traffic volumes and vehicle classification.
- Coverage (HPMS) counts- This involves 48-hour monitoring of traffic volumes, vehicle classification, and truck weights. Truck weights are currently not a reporting requirement, and are thus only being monitored on an experimental level. This is a subset of the overall coverage counts.
- Special Request short-term counts- This is usually used for project-specific purposes, such as turning volume counts for signalization.

Coverage counts for the County Flow Maps and other uses

The overall coverage count program was in existence before the HPMS, and has a very wide scope. Under this program, the Traffic Statistics Section of INDOT conducts 48-hour counts on all state roads in each of the 92 counties in the state of Indiana. This unit also counts non-state rural and non-state small urban HPMS road sections. With the exception of the truck weight aspect, the HPMS program can actually be considered a subset of the CFM coverage count program. A few non-state city streets and county roads are also counted as part of the CFM program. Currently, each county is counted on a rotating schedule of approximately four to five years.

The CFM program generates data that is used to support the HPMS in providing more accurate estimates of highway travel. The 48-hour count results are used to generate state-wide figures of AADT. To arrive at the estimated AADT, an axle correction factor is applied to convert the axle counts into vehicle counts. This count figure is then adjusted by multiplying it with a monthly seasonal variation factor (obtained from analysis of ATR data) to annualize the count into a 24-hour AADT estimate.

Other uses of the CFM program include preparation of traffic flow maps that are used by various state departments in highway administration, and generation of data for the management systems and other end users. The county flow maps are a collection of all AADT estimates for the entire state. Each map shows a county, the state roads contained in that county, and a number-letter code that has been assigned to various segments of the state roads. A listing, provided to the right of each map, shows the state road number, the number-letter code that corresponds to the map, the traffic volume estimated as AADT, and terminal points to which the estimated AADT applies. A sample of a county flow map report is provided as Appendix 17 of the main report.

Coverage count locations are updated periodically in response to changing situations such as new traffic generators and new construction of roads, intersections, and bridges.

There is no indication of required count frequency for the CFM coverage count program in available INDOT or FHWA literature. Currently, the counts on the Indiana's Interstate system are being carried out on a two-year cycle. However, from the 1995 edition of the County Flow Map book, most of the non-interstate roads are counted in a cycle of approximately 5 years. Significant efforts are being made by INDOT to reduce this cycle duration to about 3 years, in order to improve the "currentness" (and hence, usefulness) of the coverage count data.

Traffic data needs of the CFM coverage count program:

1. Type of data required (count types):
    - Traffic volumes (for estimation of AADT and DVMT)
    - Vehicle classification (Percentages of commercial vehicles)

2a. Frequency (Option 1):

- Interstate roads in all counties: 2-year cycle
- Non-Interstate roads:

  - Low-growth counties: 4 year count cycle
  - Average-growth counties: 3 year count cycle
  - High-growth counties: 2 year count cycle

2b. Frequency (Option 2):

- NHS roads in all counties: 2-year cycle
- Non-NHS roads
  - Low-growth counties: 4 year count cycle
  - Average-growth counties: 3 year count cycle
  - High-growth counties: 2 year count cycle

3. Duration: 48 hour minimum count duration

4. Number of data collection sites. In any county, selection of the locations of sites for counting are based on the following considerations:
   - Road sections between any two major intersections or interchanges
   - Road sections between a major intersection of a state road and a county or state border
   - Points on the non-state road system that pass over or under a state road
   - Contiguous segments for which traffic volumes differ by more than 10%, because of traffic generators, even if this would lead to further segmentation of a road section between major intersections

In order to concentrate its data collection activities on roads of higher priority, INDOT has maintained a monitoring cycle of 2-year length for Interstates. This cycle length for Interstates in all counties should be maintained, and possibly extended to all roads on the National Highway System (NHS). Also, it is desired that the coverage count activities would focus more closely on faster growing areas of the state. Hence 2-, 3-, and 4-year cycle lengths chould be used for monitoring non-Interstate or non-NHS roads in slow-growth, average-growth, and fast-growth areas respectively.

The option of concentrating traffic monitoring activities on NHS roads rather than only Interstates, is recommended. This is because the signing of the National Highway System Designation Act in November 1995 took the nation beyond the Interstate era, setting in place a national road system that would be the focus of attention over the next few decades. Roads comprising the NHS were selected for their important contribution to the nation's economy, defense and mobility. The NHS comprises only 4 percent of the nation's road network in terms of mileage, yet it carries over 40 percent of all highway traffic and 75 percent of all heavy truck traffic, and 90 percent of the entire population of

the U.S. lives within 8 km of an NHS route (*Public Roads*, Spring 1996 Edition). All Interstates are included in the NHS.

Coverage counts for HPMS

The HPMS (Highway Performance Monitoring System) is described by the FHWA as a nationwide road inventory system that assesses system lengths, use, condition and operating characteristics of highway infrastructure. The operating characteristics include volumes, vehicle classifications and weights of highway traffic. On p. I-7 of the *HPMS Field Manual*, it is stated that the responsibilities of the state agencies include "... collection/assembly of timely reporting of high quality HPMS data in prescribed codes and formats." The *Traffic Monitoring Guide* of the FHWA, on page 2-4-3, states that "The HPMS element provides a minimum coverage framework of short-term counts for AVDT and AADT estimation ... The Guidelines of the HPMS (coverage) element recommend the use of 48-hour counts on the full sample of HPMS sections over a three-year cycle."

The traffic data needs and adequacy of the INDOT's HPMS coverage count program has been addressed in Data Action Plan B.7 of this report. Therefore this section focuses primarily on the County Flow Map short-term counts.

Special Needs Short-term Counts

The Roadway Management Division of INDOT often receives requests for traffic data at sites for which data generated by the existing coverage or continuous count programs cannot be extracted and reported, for a variety of reasons that may include the following:

- The location of the nearest ATR is too far to provide data that is adequately representative of travel at the desired site
- The most previous coverage count carried out at or sufficiently near the desired site is so outdated that it cannot represent current trends
- Data from a recent 48-hour coverage count is available, but the duration of the special count required is longer that 48 hours.
- The count type required at that site is not made available by the existing continuous or coverage count programs, e.g., turning movements

The duration of these special request counts is usually short-term, and are used for preliminary engineering or project-specific purposes. According to the AASHTO Guidelines for Traffic Data Programs, p. 13, "Special request counts include rail crossing studies, bridge crossing studies, legislature requests, signal timing, signal warrants, capacity analysis...."

Stages of work cycle for short-term counts

The complete work cycle for short-term counts involves two stages: Data collection, and data analysis. Details of each stage of the cycle are as follows:

A. Data Collection Processes

1. Number and distribution of data collection sites
2. Exact locations of data collection sites
3. Installation procedures
4. Equipment testing
5. Frequency and duration of data collection
6. Special request procedures

B: Data Analysis Procedures

1. Data Editing (Error detection and feedback)
2. Data Summarization
3. Data Reporting.

Part A: Validation and documentation of existing short term traffic data collection processes.

A.1: Number and distribution of data collection sites.

Random site selection for short-term coverage counts is carried out at the INDOT Central Office, and a list of the chosen sites is forwarded to the supervisor in charge of field data collection. With the advent of the HPMS program, this selection has been carried out with priority given to HPMS sections, i.e., ensuring that HPMS sections are not excluded.

A.1.1: Coverage Count Sites for HPMS

The selection of data collection sites for HPMS should be based on a statewide statistical sample. In order to obtain a satisfactory degree of precision for reported traffic data, the *Traffic Monitoring Guide* of FHWA (1994) requires that, over a three year cycle ...

- traffic volume counts should be carried out on all HPMS sections.

- vehicle classification counts should be carried out at 300 HPMS sections distributed among the road functional classes depending on their volume contribution.

- truck weight counts shall be carried out at 90 HPMS sections (chosen from the 300 vehicle classification sites) distributed in a method similar to that for the vehicle-classification sites.

Currently, INDOT carries out short-term traffic volume and vehicle classification counts at all non-urbanized HPMS sections and rural, small urban and urbanized HPMS sections on state highways, while the metropolitan planning organizations (MPO's) are responsible for collection of traffic volume and vehicle classification data at HPMS

sections on local, county and city roads in urbanized areas that have over 50,000 population.

There are no truck-weighing short-term coverage counts currently being carried out by INDOT. However, INDOT field personnel are currently testing some portable weigh-in-motion equipment as part of a re-activation exercise for this count program.

The *Traffic Monitoring Guide* recommends that, because short-term data can be obtained from the data generated by the permanently-installed continuous count equipment (ATRs), short-term data collection may be carried out at a site only in the absence of a permanently-installed equipment.

The adequacy and accuracy of the existing data collection process to satisfy the traffic data needs of the HPMS, as well as a documentation of existing procedures and processes, have been addressed in detail in Section B7 of this document. In that section, number and distribution of additional count sites required for each count type have been recommended.

A.1.2: Coverage Count (CFM) Sites

The CFM program is structured by INDOT such that the flow of traffic on public roads within every county is monitored. The CFM coverage counts are carried out on each segment of the state highway system and some local streets in the urban areas. Some segments have more than one count. The results from such counts are used for various purposes, such as the production of traffic flow maps for publication in an annual report, and the estimation of VMT in each county. Adequacy of CFM counts has been addressed in Data Action Plan D1.

A.1.3: Sites for Special Request Counts

For special request counts, it is not possible to pre-determine the number, type and sites of counts as is done for the HPMS and CFM counts. This is because such information is provided by the agency requesting the count usually without much advance notice. Hence INDOT assumes a contingency number of special request counts in order to plan ahead for such traffic monitoring activities. At present, there is no short-term count carried out at the specific request of any management system. This is because data required by the management systems are obtained from data generated under the Continuous or Coverage count programs. The traffic data needs of the various management systems have been assessed in Data Action Plans B1-B6 of this study.

A.2 Precise locations of short-term data collection sites

The traffic data-collection analyst at INDOT periodically reviews the randomly selected potential sites for sampling. The field staff ensures that the selected location is not on a

curve or at a section where installation of the equipment may compromise their safety or accuracy of collected data.

Other factors that govern the decision to select a particular site for the counting session include roadway surface characteristics, and road construction activities in vicinity of the potential site. The data collection technicians shift sites to more acceptable locations, with the approval of the analyst.

According to the *AASHTO Guidelines for Traffic Data Programs*, page 12, "The reason for deleting [any] potential sites must be documented and provided to the manager of the Traffic Data Program."

A.3 Installation Procedures.

On page 25 of the *AASHTO Guidelines for Traffic Data Programs*, it is recommended that "...each agency should define and document installation procedures to ensure consistency in automated traffic data collection."
INDOT's contact person for this data action plan states that the main reference, collectively retrieved from the *Traffic Monitoring Guide*, *AASHTO Guidelines*, various INDOT memos, and experience earned by INDOT's personnel over a substantial period of time, is the "Manual for Traffic Counter Technician IIIs".

Setting up of INDOT's short-term traffic-data collection equipment, data collection and other related activities are supervised by a qualified data collection supervisor with the assistance of trained field technicians. INDOT's traffic counter technicians receive approximately ten weeks of supervised training at the beginning of their employment and consequently are relatively experienced before being allowed to work alone. According to the INDOT contact person, this training covers all aspects of traffic data collection, including safety, the manufacturer's recommendations, and precautions to ensure collection of accurate data.

The general procedure that INDOT field staff use for each count is as follows:

1. The exact location of set-up is selected carefully. Using a map, the approximate desired location of the count station is determined. After the preliminary screening of potential data collection sites by the field technician, each selected location is checked to ensure that such a location is not near an intersection or driveway.

2. The technician then drives to the location and selects the precise spot for the count.

3. The road tube(s) are set in the manner prescribed for the type of count to be carried out, i.e. 1 for volume, 2 for classification.

4. The road tube(s) are connected to the recording unit, i.e., counter/classifier, the recording unit's battery is checked, and then the unit is programmed for the type of count to be taken.

5. An unspecified number of vehicles are observed to ensure that the counter/classifier is accurately counting or classifying.

6. The counter/classifier is secured with cable and lock.

7. The location, date, time and counter/classifier serial numbers are noted, and the device is left to operate.

Set sensors are made less than a full lane in width, to forestall miscounting by detection and counting of vehicles moving in opposite direction or on adjacent lanes.

Also, the field crew is careful to ensure that sensors are set perpendicular to the direction of travel, otherwise the presence of a single axle may be erroneously recorded more than once.

Pneumatic road tubes used for short term traffic data equipment are installed such that the tube clamps are held down with nails at the outside edge of the pavement. The clamp is tightened until the tube is just taut enough to ensure that motion by passing vehicles can be detected.

For vehicle classification, two tubes are used. As much as possible, the field crew ensures that both tubes are of similar characteristics, i.e., length, type, and date of purchase.

The recording unit is usually placed near the outside edge of the road, at a spot that is not prone to damage from vehicles or other hazards. Further details of the procedures adopted by the INDOT field data collection staff are found in the *FHWA Traffic Detector Handbook,* which is a reference used by INDOT's traffic data collection teams.

Some MPOs in the State of Indiana have documented the procedures they have adopted for data collection and analysis. Other MPOs should be encouraged to follow this example.

A.4 Equipment testing

Evaluation of existing procedures for equipment testing is covered under *Data Action Plan D1 (Short Term Equipment Adequacy and Accuracy).*

A.5 Frequency and duration of data collection.

On page 24 of the *AASHTO Guidelines for Traffic Data Programs*, it is stated that "short-term traffic coverage counts for federal reporting purposes under the Traffic Monitoring

Guide and Appendix K of the Highway Performance Monitoring System Manual should be conducted for a minimum of 48 consecutive hours. All other state agency traffic monitoring activities on rural roads should also be monitored for a minimum of 48 consecutive hours".

INDOT's policy is that all short-term counts use a duration of 48 hours. With regard to count frequency, efforts are currently underway at INDOT to ensure that these counts are carried out in within the desired cycle lengths for HPMS, and for the overall (CFM) coverage counts.

A.6 Special request procedures

End-users of traffic data may require that special counts be carried out at certain locations and for durations that are not covered under the existing count programs. Such special requests should be accompanied by a completed standard form (sample shown in Appendix B3-a. On this form, the location (including a map sketch), duration, frequency and count type needed should be indicated by the person requesting the count.

Part B: Validation and documentation of existing procedures for analysis of short-term traffic data.

Analysis of traffic data consists of:

1. Data Editing
   - Error detection and feedback

2. Data summarization
   - Estimation of site-specific statistics
   - Estimation of system-level statistics
   - Computation of adjustment factors.

Summarization is an important part of traffic monitoring, and it is necessary that data submitted to the end-users are consistent, appropriate, clear and reproducible. It is also important that adequate information be submitted along with the data summaries so that such summaries are readily understood.

Currently INDOT summarizes traffic data in two ways:

- Site-specific traffic data summaries, which generate statistics such as AADT and relate to a point or segment of roadway,

- System-level traffic data summaries, which generate statistics such as VMT and relate to a network system or groups of roads.

Another aspect of data summarization that actually precedes the estimation of system-level and site-specific statistics is the calculation of adjustment factors. According to the

AASHTO Guidelines for Traffic Data Programs, "Among state agencies, traffic data from permanent counters and short-term counts are summarized to represent common characteristics". These characteristics, according to the *AASHTO Guidelines*, include:

- seasonal variation in traffic, determined by a **seasonal adjustment factor**
- ratio of total axles to total vehicles, determined by an **axle correction factor** for short-term volume counters that record only axle impulses
- annual growth determined by an **annual growth factor**, so that data can be extrapolated for site which were not counted in the prior year(s)

B.1 Editing of data from short-term coverage counts

After short-term traffic data has been collected, they should be edited. Editing of short-term traffic data ensures the validity of field data before such data are summarized and reported to the end-users and relevant agencies.

Errors in short-term coverage counts may be caused by battery power failures and equipment malfunction. Such erroneous data should be identified and excluded from the data-base. It is also essential that the detection and identification of such data at INDOT Field Office be immediately reported to the INDOT field crew in charge of such equipment, so that the crew can identify the cause of the problem and take the appropriate remedial action.

The Traffic Statistics Section of INDOT has recently established a procedure where bad data is detected at the site and deleted by field crew, and the count re-taken. This way, very little bad data reaches the head office, and much time and effort are saved in data editing and processing.

According to the *AASHTO Guidelines for Traffic Data Programs*, "If minimum acceptable hours of valid data remain after such deletions, the count [may be] processed, summarized and reported. [However] if the minimum acceptable consecutive hours of valid data do not remain, the traffic count should be retaken."

According to the *AASHTO Guidelines*, there are three main concerns for editing traffic data:

- Machine malfunction
- Intended use of data
- Context of data collection.

The *AASHTO Guidelines* (pages 31-37) provide some specific tests for each concern. These are discussed below.

B.1.1 Machine Malfunction

Devices installed to monitor traffic may malfunction. Malfunctions may occur in any of several ways during traffic monitoring activities. Modes of malfunction include road-way sensors (for example road tubes, loops, or tape strips), hardware system electronic malfunction, failure of power supply and errors associated with data transfer links.

Device malfunctions are the easiest problems to detect, because they usually result in a recognizable data pattern. The pattern may be a series of zero recordings (the most frequently occurring malfunction), a random series of very large recording, a series of repeated values (often a device-specific, binary multiple such as 1024, or a power of 2, such as 2,4,8) or no recording at all. When these conditions occur, the device is reset.

It is clear that machine malfunction records of the types described above are such that no indication of the true traffic count can be discerned from such records. These records may be used in computerized editing programs for identifying patterns of specific device malfunction, and in manual editing programs for training editors to recognize problems. Data that are a result of machine malfunction should be retained for research and audit purposes but should not be forwarded for summarization, reporting and retention.

Repeated values can be used to identify invalid records manually or electronically. For example, a series of identical values recorded over a period of time is suggestive of equipment malfunction.

Machine malfunction can also be indicated by the directional distribution of traffic. To examine directional distribution of traffic, the morning and evening peak hour volumes may be compared, at locations having a device in each direction. In most instances the morning and evening peaks will occur in opposite directions. Recorded values that do not conform to such patterns at locations where such patterns are expected, are indicative of equipment malfunction, unless there is a cause to believe that such anomaly is the result of special trip generation circumstances.

If the daily traffic is monitored in each direction, the data should also be checked to determine the directional distribution. According to the *AASHTO Guidelines*, if the directional volume is not evenly divided, such as not within ± five percent, the analyst may attempt to confirm the pattern by examining the temporal context (checking earlier traffic counts at the same site) or the spatial context (nearby counts on same roadway). The analyst frequently must rely on accurate information on the count location to determine the validity of the count.

However, the analyst should note that there are limits to the use of directional distribution of traffic as an indication of machine malfunction. On some roads, particularly in recreational areas, on one day traffic will be unbalanced in one direction while on another day traffic unbalanced in the opposite direction. If this is observed, it should be considered typical. The location of service roads and access points to freeways may also cause unbalanced traffic flow. These traffic patterns should be recorded so that future data can be better edited against actual traffic information.

Short-term data may be influenced by battery problems, or damaged or missing road tubes. The use of directional distribution, as described above, is important in editing short-term data.

General patterns of traffic characteristics may be used in relation to short-term counts. Site-specific data and patterns may be used in editing nested traffic counts. In nested counts more than one data element is recorded during the same field activity. The specific measurements of the permanent classifier can be compared with the specific classification measurements of the [short-term] device. If there is a discrepancy, manual field observations or automatic short-term counts can be taken to check the accuracy of the permanent recorder. If the permanent device is accurately collecting data, the data from the [short-term] device may be questioned and the device re-calibrated.

An example of the benefits of nested traffic counts is the use of a short-term portable Weigh-in-Motion (WIM) device to weigh vehicles near the site of a permanently installed vehicle classifier. Such an arrangement provides the ability to check shared data collected by two devices located at points where traffic patterns are expected to be similar.

B.1.2. Intended Use of Data

The validity of traffic data is not limited to the issue of whether the data is questionable because of machine malfunction. Data validity also depends on the intended use of the data.

Traffic data are collected for a wide variety of uses. The purpose for which the data will be used may dictate the count location, duration, equipment type, and whether or not adjustment factors should be calculated and applied. Problems can arise when data collected, and perhaps adjusted, for one purpose are used for another. In order to minimize these problems, application of the principle of Truth-in-Data is recommended by the *AASHTO Guidelines* (p. 34). Under this approach, data would be stored as recorded, then factored using standard techniques. Suspect or adjusted data would be identified.

Short-term samples of traffic that represent atypical traffic conditions should be labeled and retained, but should not be used to estimate annual traffic summary statistics. The data should be retained because they may be useful in specific traffic studies, while being labeled as non-representative of typical traffic.

Data collected during holidays, sporting events, parades, or traffic incidents are commonly referred to as "atypical". This means that although the records may be traffic measurements, they may be unsuitable for some purposes. For instance, if an event has a significant effect on the calculated average traffic during any period of interest, the data should not be summarized and used as the basis for estimates of that period. If the data user is interested in peak hour volumes, the use of an hour in which there was a traffic interruption (such as an accident, fire, or parade) or a surge in traffic (due to clearance of an obstruction) would be unacceptable. The data should be labeled and retained because they may be useful in specific traffic studies. If conditions such as construction of detours exist long enough to affect daily volumes, data for the entire period should be labeled.

The *AASHTO Guidelines* suggests that data should not be labeled as atypical when traffic events occur with regularity, or when a new pattern of traffic demand is being monitored. An example of a regular pattern would be roads in close proximity to a stadium. In such a situation the 30th highest hour could be within the period of an event. An example of a new pattern would be traffic demand caused by a change in land use.

The data validity problem is in part whether or not the conditions under which traffic were monitored are appropriate to specific uses. Traffic data edits should include appropriate labeling so the data can be accurately summarized, reported and applied.

Short-term traffic data edits, manual or electronic, can check for appropriate month, day, and duration of count. The initial edit is for the duration of the traffic count. The concern is whether the minimum duration has been completed. The minimum short-term count duration for estimating urban annual traffic summary statistics is 24 hours.

Traffic edits should check for appropriate month and day count. If short-term count data are to be used to compute design-hour traffic or other estimates representing typical traffic demand, care should be taken to avoid counting during atypical periods. Atypical periods include holidays, weekends, and special events and the days adjacent to those events. Substantial errors will be introduced if data collected during atypical periods are used in the computation of design hours, or factored to estimate typical travel volumes. Should the data be used for factor development and applied to other short-term counts, the errors could become widespread.

If short-term coverage count data are to be used to investigate the traffic flows produced by special events, the count edit similarly must check for month and day count. The count strategy would be directed to monitor traffic demand during the atypical period.

Some states maintain a record of activities that might influence traffic characteristics. For questionable counts, analysts may check such records for events such as holidays (public and religious), school and sporting events, weather conditions, construction, and accidents.

Editing should identify and label data that should not be summarized for general traffic reports representing typical annual traffic. This would, for example, restrict traffic counts used in estimating Annual Vehicle Distance Traveled (AVDT). While many states currently perform this "exclusion" process manually, it should be their objective to move toward computer-aided traffic data processing and editing, so that such "exclusions" may be more easily carried out.

B.1.3. Data Context

Traffic measurements are not only examined for machine malfunction and intended uses. They are also examined in the context of other traffic counts. The context is both the history of traffic at the same location, which is termed the temporal context, and traffic characteristics at other points along the same roadway, termed the spatial context. Editing data for temporal and spatial context identifies questionable data for further professional review. This type of editing can also help identify equipment malfunctions.

The first edit context is temporal. A permanently installed traffic device will have historical data from previous years. A short-term traffic site may have been previously counted. Collected data that shows significant variance from historical traffic characteristics may be flagged for further review.
The second edit context is spatial. Traffic recorded at one location along a roadway does not exist independently of the roadway as a whole. By comparing short-term traffic counts along a roadway, the analyst can identify discontinuities and possible problems with one or more traffic counts.

B.1.3.1 Temporal Context of Data

Editing traffic data in a temporal context examines the current measurements in relation to historical measurements at the same site. Some patterns of traffic characteristics are acceptable if they are repeated regularly and unacceptable if they are not. Deciding when a pattern is unusual becomes a key issue.

Some attempts have been made to use techniques based on data patterns to determine the acceptability of short-term traffic data. They have had limited success because statistical test of traffic are commonly based on the long-term patterns described above. In the case of traffic volume data from permanent ATRs, long-term data variation is more understood because the traffic sample of traffic data at the site approaches the population of traffic data at a site. However, the application of statistical techniques to edit short-term count at random locations is problematic. There are seldom any historical data at most short-term count locations, and the data that exist are inadequate to establish accurate statistical limits for each hour.

While data patterns cannot be used to edit short-term traffic count data, thresholds of hourly variance can be applied. Electronic edits, such as records exceeding a defined threshold in vehicles per lane per hour, can indicate volumes in short-term counts for further review by the analyst.

B.1.3.2 Spatial Context of Data

Short-term traffic count that exceed defined thresholds are flagged for further review by the analyst. The usually consists of examining the data in a spatial context. This examination should involve data from other permanent or short-term counts on the same road, during the same time period as the questionable traffic count.

Examination of the spatial context of a traffic count can be facilitated by automated analysis using Geographic Information Systems, or manually plotted maps, to display traffic count data. Multiple counts and traffic summary statistics can be displayed graphically on a road map. Discontinuities in traffic measurements along a roadway can be readily seen by data analysts. If a traffic count is inconsistent with another traffic count during the same period on the same roadway, and no explanation of the count variance can be provided based on land use, the related count should not be accepted for summarization until another count can be taken and compared.

Where there are inconsistencies, counts should also be initiated on the adjoining segments to confirm the validity of all counts. What appear to be "consistent" counts may have been taken with the same malfunctioning traffic recording device.

There is another benefit of a Geographic Information System (GIS) for spatial context editing of traffic data. Using a GIS, land use (and potential trip generators or attractors that might account for traffic change) can be simultaneously displayed with traffic volumes.

When using a GIS, it is recommended in the near-term that traffic measurements be examined along the same roadway. In the long-term development of traffic edits, it is recommended that spatial traffic editing be integrated with Geographic Information Systems.

Editing Vehicle Classification Data

Edits for vehicle classification are similar to those for traffic volume. Classification edits are similar to traffic volume edits, whether vehicle classification is by length or axle configuration. The same concerns of machine malfunction, labels for data use, and temporal and spatial contexts apply.

Lane distribution is important in vehicle classification. In order to produce a classification count summary of average weekday traffic, data must be collected in each lane of travel. Such data collection will permit the temporal context edits to include comparisons of historical and current vehicle classification by lane.

In order to edit manual classification data, whether at an intersection or on a road segment, a completed field log should accompany each manual classification dataset. The log would include location, direction, data, time and weather conditions. The purpose of the log is to assist the analyst in the editing process and to assure that the data will be processed and reported for the proper highway lane and direction.

B.2 Estimation of system-level statistics

Vehicle Distance Traveled (VDT)

The Traffic Monitoring Guide, on p. 3-3-1, states that the major purpose of the HPMS element is to provide a limited core framework or structure of randomly selected HPMS standard sample sections throughout the state. The TMG further states that this core is a systems tool that will completely satisfy the needs for statewide information such as system vehicle distance traveled (VDT).

According to the TMG, the following steps are used in estimation of annual VDT :

1. Compute AADT estimate for each HPMS standard sample section.

2. Section AADT is multiplied by section length and HPMS stratum expansion factor, to get expanded DVDT.

3. Sum all expanded section DVDT estimates of all the sample sections within the stratum.

4. Sum the DVDT of the appropriate strata to get aggregate DVDT estimates at any level (volume group, functional class, area type etc.).

5. Multiply DVDT estimates by 365 to get annual vehicle distance traveled AVDT.

A sample form for the computation of AVDT using these guidelines is provided as Appendix H-b.

Also, a method of estimating the accuracy of AVDT values, based on TMG guidelines (p. 3-3-12) is provided as Appendix H-f.

B.3 Estimation of site-specific/system level statistics

Average Annual Daily Traffic Volume (AADT)

The method for estimating AADT from coverage counts involves the following steps:

1) Grouping together ATR sites into similar patterns or groups of temporal traffic volume variations using a method such as clustering
2) Determining average volume expansion factors for each ATR group
3) Assigning road sections (on which short-term counts have been taken) to one of these ATR groups
4) Applying the appropriate volume expansion factor to the assigned road section to get the AADT estimate for that section

The TMG procedure for estimating AADT follows these steps, and is quite straightforward. The 48-hour count taken at sample sections during the current year may require adjustment by seasonal adjustment factors and axle correction factors. For sections not counted during the current year, it is necessary to include a growth factor in the estimation of AADT.

According to the TMG, "the recommended method for expansion of 48-hour counts is to convert each of the two separate 24-hour periods to AADT and then average".

The TMG proposes the following equation to estimate AADT:

$$AADT_{hi} = ½ * SUM(Vol_{hi} * M_h * D_h * A_h * G_h)$$

where $AADT_{hi}$ = the annual average daily traffic at location i of functional class h,

Vol_{hi} = the 24-hour axle volume at location i of functional class h,

M_h = the applicable monthly factor for functional class h,

D_h = the applicable day-of-week factor for functional class h (if needed)

A_h = the applicable axle-correction factor for functional class (if needed)

G_h = the applicable growth factor for functional class (if needed)

A sample form for the computation of AADT using these guidelines is provided as Appendix H-b.

Some issues associated with computation of AADT

- Some equipment units automatically divide by two to produce a "vehicle" count. In such cases, the number of axles can be estimated by multiplying by 2 or by modifying the software to report axles.

- The formula indicated above is for the general case. In some cases, the application of some of the factors may be unnecessary. For example, automatic equipment that counts vehicles does not require axle correction. Also, an agency may not require day-of-week factors. In such cases these factors are assigned a value of 1.

- An estimate of precision, according to the TMG, "...cannot be directly developed since the application of system (group) factors to a site-specific short count is an inference rather than the traditional expansion from a sampling process. Precision estimates apply to sampling processes which use probability theory to relate the size of the sample to the precision of the estimate developed from the sample."

- According to the TMG (p. 3-3-12) an approximate estimate of the relative variance coefficient as a percentage of the AADT is given by the following equation (the relative variance coefficient is defined as the standard error divided by the estimate) :

$$C = \text{Square Root}\,(CV^2 + CM^2 + CD^2 + CA^2 + CG^2)$$

where

C = relative variance coefficient as a percentage of the AADT,
CV = relative variance coefficient of the 48-hour volume,
CM = relative variance coefficient of the monthly factor,
CD = relative variance coefficient of the day-of-week factor,
CA = relative variance coefficient of the axle correction factor, and
CG = relative variance coefficient of the growth factor.

The equation shows the precision gained by increasing the number of sites used to develop the factors. *The equation cannot be used to estimate the precision of a site - specific estimate.* The equation indicates that the more factors used the larger the error, incorrectly implying that the error can be minimized by not using factors. It is obvious that a short uncorrected count is less reliable than a count that has been adjusted by seasonality, axle correction, or growth.

- The TMG presents a method to estimate the precision of AADT estimates derived from short counts and adjusted by system factors. Such a method would require approximations derived by simulation at continuous ATR locations. This involves estimating the AADT using random 48-hour periods (or all such periods during the

year), adjusting the counts using the system factors, computing the differences from the actual AADT at the ATR site, computing the coefficient of variation (CV) of the error from all the 48-hour periods, and then averaging the CV's from all ATR locations within the functional class or seasonal group used.

A form for estimating the accuracy of AADT values, based on TMG guidelines (p.3-3-11) is provided as Appendix H-d.

B.4 Estimation of Adjustment Factors

B.4 (i)Calculation of Growth Factors

Annual growth of traffic is represented by an annual growth factor, so that data can be extrapolated to obtain current traffic volume at a site that was not counted in the prior year(s), or to predict future traffic volume at a site given a base year count.

Growth factors at a point are best estimated using the following assumptions:

1) A continuous ATR is present at the point.
2) Data from the ATR are completely reliable.
3) Differences in volume from year to year are attributed solely to growth.

In reality however, very few points are at ATR locations, and data from all ATRs are seldom completely error-free. Furthermore, volume differences at a point from one year to another are not always due solely to growth, but may also be caused by other circumstances such as construction on alternative or parallel routes, traffic seasonality due to terminal dates of educational institutions, vacation resorts, etc.

Such oft-encountered violations of the assumptions lessen somewhat the predictive power of growth factors. Hence computation and application of growth factors for specific sites or points are to be carried out with extreme caution.

Growth factors on a system level can be developed from all the continuous ATR's over the entire state road network, and the averaging effect mitigates the effect of the extraneous factors.

However, as in the case of most states, the number of continuous ATR's in the State of Indiana is very limited and is far from adequate to enable development of accurate system-level growth. This is because growth may not occur at the ATR locations, or may rather occur where there are no ATR locations. Thus growth factors computed from such ATR locations would be misleading.

According to the TMG, p.3-3-13, "The location of ATR stations is very important in [the computation of system-level growth factors] since growth is very location specific. Estimating growth in urban areas using a small number of stations, or stations located in rural or other urban areas is not recommended".

37. Oregon Department of Transportation (1997), *Traffic Monitoring System: State of Oregon*, Oregon Department of Transportation.

38. Peek Traffic Inc. (August 1997), *Product Catalog for Traffic Data Collection Equipment*, Peek Traffic Inc., Sarasota, Florida

39. Polk A. et al. (1996), "Field Test of Non-Intrusive Traffic Detection Technologies", *Proceedings of National Traffic Data Acquisition Conference (NATDAC) 1996*

40. Ritchie, S. (1992), "*A Statistical Approach to Statewide Traffic Counting*", Transportation Research Record No. 1271, Transportation Research Board, Washington, D.C., U.S.A.

41. Saito, M. and Patel, R. (1995), "*Evaluating the Efficacy of a Microwave Traffic Sensor in New York City's Freeway and Street Network*", New York City Department of Transportation

42. Sharma, G. and Rizak, S. (1996), "*Statewide Traffic Volume Studies and Precision of AADT Estimates*", Journal of Transportation Engineering, Vol. 14., American Society of Civil Engineers.

43. SAS Institute Inc. (1996), "*A Formula for OLAP Success*", SAS Institute Inc., Cary, North Carolina.

44. SAS Institute Inc. (1996), "*The SAS System for Information Delivery: Executive Summary*", SAS Institute Inc., Cary, North Carolina.

45. SAS Institute Inc. (1996), "*Rapid Warehousing Methodology*", SAS Institute Inc., Cary, North Carolina.

46. SAS Institute Inc. (1994), *Statistical Analysis Software Version 4.1 and Users Manual*, SAS Institute Inc., Cary, North Carolina.

47. Sweet, R.J. and Lockwood, D.N. (1983*), The Accuracy and Estimation of Annual Traffic Flow*, South Africa Ministry of Transportation.

48. Timemark Inc., (July 1997), *Product Catalog for Traffic Data Collection Equipment*, Timemark Inc., Salem, Oregon.

49. Wilkinson, J. E. and Albright P. D. (1990), "*Design, Development and Implementation of a Statewide Traffic Monitoring System*", Transportation Research Record No. 1271, Transportation Research Board, Washington, D.C., U.S.A.

According to the TMG, p. 3-3-13, the equations used for computing growth factors based on continuous ATRs or [HPMS] current coverage counts are as follows :

$$G_n = \frac{AADT_t}{AADT_{t-1}}$$

where G_n = growth factor of location n
$AADT_t$ = annual average daily traffic (AADT) for year t
$AADT_{t-1}$ = AADT for year t-1.

b) Annual growth factor for a functional class

$$G_h = SUM\ (G_n / N_h)$$

where G_h = growth factor for functional class h
G_n = growth factor of station n within functional class h
N_h = number of stations in functional class h

c) Annual statewide growth factor

$$G = \frac{1}{V} SUM\ (V_h * G_h)$$

where G = statewide growth factor
V_h = VDT or DVDT for the functional class h,
V = statewide VDT or DVDT, i.e, total for all functional class

The *Traffic Monitoring Guide* excludes the local functional class VDT from the parameter V, i.e., statewide VDT.

Precision of growth factor estimates:
a) Standard error (variability) of annual growth factor for a functional class, S_h

$$S_h = SQRT\left(1/(n_k) * SUM\ [(G_n - G_h)^2 / (N_h - 1)]\ \right)$$

where symbols are as defined in the TMG and shown above

b) Standard error of the statewide annual growth factor

$$S = SQRT\left(SUM(S_h)^2 \right)$$

The TMG further states the following points about computation of growth factors :

- The procedures for the estimation of growth factors based on the HPMS core framework are recommended in the Guide, as stated earlier, because of the belief that the large spatial sample size of the coverage program is superior to the temporal sample size of the limited continuous program.

- Several different procedures could be used to estimate growth rates and the procedure presented here is just one of many possible. The annual counts could be used directly, converted to AADT, or converted to system VDT through the HPMS procedures before proceeding to estimate growth rates. Because of the emphasis on point-specific estimation and to provide a firm starting base, *the recommended procedure is to convert to AADT all current year counts before developing the growth factors.* This will allow the development of point-specific, system, and statewide estimates starting from the basic building block in traffic counting, the AADT.

- The first step of the procedure is then to compute the AADT at each of the coverage count sections monitored during the current year. A direct point-specific growth estimate can be derived based on the ratio of the current year AADT to the previous year AADT. Because of the HPMS sample design, aggregations by HPMS strata or combination of strata could be developed as needed. The recommendation is to develop factors at the functional class level for use in the expansion of sections not counted during the current year to AADT. The reason for the recommendation procedure is that extraneous effects will be averaged out resulting in a better estimate of system growth.

- It is appropriate to mention that computation of point-specific growth estimates from the coverage counts would indicate whether the point values differ significantly from the system estimate and whether the system value may be inappropriate for point-specific or area concerns. This is where the ATR approach breaks down because of the very limited number of stations.

- Plotting the coverage count growth information on a map would be invaluable in estimating pockets or patterns of growth and in the detection of errors. This step is very important because growth tends to occur in some parts of the system and not in others. The use of functional class system factors may not be appropriate, particularly when dealing with large urban or suburban areas where growth patterns are concentrated in some areas and absent in others. State agencies may prefer to develop growth factors in a more disaggregate manner that reflects area patterns. The coverage count approach can support such alternatives.

Forms for estimating growth factors and their accuracy, based on TMG guidelines (p. 3-3-14), are provided as Appendices H-c and H-f respectively.

B.4 (ii) Calculation of Axle Correction Factors :

Axle correction factors are used to convert axle counts to obtain true vehicle counts at a data collection station. The application of axle corrector factors depends on the type of equipment in use. Vehicle detectors do not require axle adjustment because such equipment records vehicle counts directly, rather than axles. The extensive use of axle counting equipment in INDOT's coverage count program necessitates the development and application of axle correction factors.

The *Traffic Monitoring Guide*, on p. 3-3-17, provides a simple process for estimating these factors for specific points in the [HPMS] vehicle classification sample, and for the system in general :

The Axle Correction Factor at a point is simply the ratio of vehicles to axles as determined from a classification count.

For such point-specific concerns, the TMG states that the judgment of the analyst and knowledge of specific conditions are of primary importance. If the system-level axle correction factor is not considered appropriate, a special classification count may be required. This condition is likely to surface for specific situations such as truck routes or truck traffic generators.

For system-level purposes, the TMG recommends that axle correction factors by functional class be considered sufficient. The Axle Correction Factor for a functional class is the average of the individual factors of all the classification locations within the specific functional class.

According to the TMG, on p. 3-3-8, the application of Axle Correction Factors is a straightforward procedure: Sample sections where classification counts are taken or where vehicle-detecting equipment are used require no adjustment because the number of vehicles are obtained directly. Sample sections where [only] axle counts are taken should be assigned the factors on the basis of functional class, and these are applied in the computation of section AADT.

B.4 (iii) Seasonal Adjustment Factors.

Seasonal traffic-volume adjustment factors are used by INDOT to modify the results of short-term coverage counts to reflect annual conditions.

According to the *AASHTO Guidelines for Traffic Data Programs*, page 56, "... an important step [for calculating adjustment factors] is to determine how data should be grouped." The primary goal of grouping data is to obtain groups such that within each

group there should be similar data or data parameter values, and hence factors unique to each group can be generated and used to adjust short-term data taken at chosen sites to obtain annual estimates (e.g. AADT) of data at those sites. In this regard, variability of data or data parameter values within groups should be minimal, while variability between groups should be maximized.

The *AASHTO Guidelines* state that cluster analysis is one method of addressing this issue. The transportation agencies of some states have obtained their groups solely on the basis of functional classification, e.g., interstate roads and collectors. Other states have found that grouped data do not conform closely with roadway functional classification and have created groups based on area as well as functional classification, e.g., urban interstate and rural collectors. There are also some other some states that, in order to refine the adjustment factors, have gone further by combining aerial and functional bases of grouping with geographical considerations, e.g., northwestern urban interstate or south rural collectors.

The current INDOT list of groups for adjustment factors for traffic volumes is as follows:

1. Urban Interstates, Freeways and Expressways
2. Urban Principal Arterials and Collectors
3. Rural Interstates
4. Rural Other Principal Arterials and Minor Arterials
5. Rural Minor Collectors and Locals

Multivariate cluster analyses carried out on 1994 and 1995 traffic volume data from the ATRs have shown a fairly strong corroboration of this group list, i.e., there is a little variation within each of the existing groups, and fairly large variation between groups.

The *AASHTO Guidelines for Traffic Data Programs*, on p.56, recommends that whatever approach is developed by an agency [for grouping data] for adjustment factors, the following conditions should be satisfied:

a) within groups, variability should be minimized; while between groups variability should be maximized.

b) locations of any short-term traffic count must be able to be readily a associated with one of the defined groups.

c) the procedure that is followed should be documented and be made available upon request.

A form for seasonal adjustment factors is provided as Appendix H-h. It is essential that adjustment factors are updated annually.

B.4 (iii) -a: Typical pitfalls in calculations for Seasonal Adjustment Factors

adjustment factors. The use of these examples are purely for illustrative purposes, and do not suggest the adoption of these classes as the best grouping criterion for traffic volumes.

Type # 1

Table 1, taken from the 1995 telemetry report, contains the monthly traffic volumes observed for Interstates:

Table 1: Monthly Traffic Volumes for Interstates

STAT NUM	ADT-YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1100	17930	15672	15788	17987	18946	18431	19226	19458	14581	19132	18752	18741	18451
2100	22999	19588	19655	21732	23179	23440	24912	25219	25333	23882	23852	23577	21618
3100	9831	8089	8346	8444	9324	8795	9294	8705	9582	10866	12239	16835	7452
3110	27062	24708	23041	28288	29566	28662	26397	30360	29447	26585	25171	28882	23636
3120	10353	8372	8641	9036	9930	8279	8073	11960	8816	10804	10201	19974	10150
1110	26461	21576	20107	25671	27590	26982	29046	30093	31121	28320	26920	25825	24175
1120	38277	28998	27273	32952	36369	40112	44271	49891	49272	42437	39350	36007	32387
4140	21014	18597	17006	20106	22110	20420	22743	22527	23700	22321	21880	21413	19339
4150	25910	22040	20324	23312	25295	27388	29396	29749	30743	28231	26066	24807	23564
2110	29112	26913	25554	29470	31015	30986	32136	31615	26005	30440	29808	28913	26490
2120	11837	12475	11674	14043	14602	15949	16043	14152	0	0	16491	14636	11980
5450	34381	27538	26434	32911	34614	35787	37874	38123	39625	36084	36075	35866	31635
6140	5164	9217	8636	10064	11169	11314	11567	0	0	0	0	0	0
6150	2529	4407	4081	5024	5216	5641	5978	0	0	0	0	0	0
6160	7758	0	0	0	0	0	0	0	0	24031	23907	23148	22013
6170	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	18163.505	15511.875	14785	17440	18682.813	18886.625	19809.75	19490.75	18014.063	18945.813	19419.5	19920.25	17055.625

It can be seen from the table that some stations were not collecting any data during some months (this is indicated by the number "0"). A closer look at the site and monthly averages that were calculated will reveal that the zeros were used in calculating these average volumes. Note that Station 6160 was functioning for only 4 months during the year and the volumes were in the range of 22,000 to 24,000 vehicles per day. But when the ADT-YR was calculated, a value of 7758 was obtained. This low value is the result of including 8 zeros in calculating the average. Because the ADT-YR is used later for the calculation of the seasonal factors, the resulting seasonal factors will also be calculated incorrectly. The table below shows how the seasonal factors were affected due to including the zeros in the calculations:

Table 2: Corrected Seasonal Factors

STAT NUM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1100	1.144	1.136	0.997	0.946	0.973	0.933	0.921	1.230	0.937	0.956	0.957	0.972
2100	1.174	1.170	1.058	0.992	0.981	0.923	0.912	0.908	0.963	0.964	0.975	1.064
3100	1.215	1.178	1.164	1.054	1.118	1.058	1.129	1.026	0.905	0.803	0.584	1.319
3110	1.095	1.175	0.957	0.915	0.944	1.025	0.891	0.919	1.018	1.075	0.937	1.145
3120	1.132	1.097	1.049	0.955	1.145	1.174	0.793	1.075	0.877	0.929	0.475	0.934
1110	1.226	1.316	1.031	0.959	0.981	0.911	0.879	0.850	0.934	0.983	1.021	1.095
1120	1.320	1.403	1.162	1.052	0.954	0.865	0.767	0.777	0.902	0.973	1.063	1.182
4140	1.130	1.236	1.045	0.950	1.029	0.924	0.933	0.887	0.941	0.960	0.981	1.087
4150	1.176	1.275	1.111	1.024	0.946	0.881	0.871	0.843	0.918	0.994	1.044	1.100
2110	1.082	1.139	0.988	0.939	0.940	0.906	0.921	1.119	0.956	0.977	1.007	1.099
2120	1.139	1.217	1.012	0.973	0.891	0.885	1.004	-	-	0.861	0.971	1.186
5450	1.248	1.301	1.045	0.993	0.961	0.908	0.902	0.868	0.953	0.953	0.959	1.087
6140	1.121	1.196	1.026	0.925	0.913	0.893	-	-	-	-	-	-
6150	1.148	1.239	1.007	0.970	0.897	0.846	-	-	-	-	-	-
6160	-	-	-	-	-	-	-	-	0.969	0.974	1.005	1.057
6170	-	-	-	-	-	-	-	-	-	-	-	-
Correct Average	1.168	1.220	1.046	0.975	0.977	0.938	0.910	0.955	0.939	0.954	0.921	1.102
INDOTs Average	0.946	0.985	0.848	0.789	0.795	0.764	0.677	0.663	0.669	0.731	0.699	0.844
% Difference	-19.03	-19.26	-19.00	-19.05	-18.56	-18.55	-25.65	-30.60	-28.76	-23.38	-24.10	-23.38

Most of the seasonal factors were underestimated by 18 - 30 %. This could have serious consequences when attempting to estimate volumes on roads with similar characteristics.

<u>Type #2</u>

Sometimes, a telemetry station will either overcount or undercount the amount of traffic volumes during the month. This could be due to a malfunction during the entire month, or because the station was out of order for part of the month. As a result, including such numbers in the ADT-YR calculations will affect the seasonal factors as well. The table below is an example of such a case.

Table 3: Monthly Volumes For Urban Principal Arterials

STAT NUM	Correct ADT-YR	INDOT ADT-YR	% Diff.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1500	11998	11998	-	10356	11293	11753	11637	12719	13326	13333	13346	10141	11094	13490	11487
1520	11166	11166	-	9681	10161	10511	10202	11760	11213	10413	10675	11195	11030	17915	9241
1530	13613	12599	-7.45	12654	13027	13465	13836	13990	11489	1444	14775	14708	14393	14078	13330
2500	29163	29163	-	27329	27850	29302	29690	27808	27355	28771	29051	29833	30640	33336	28989
2510	23577	22085	-6.33	24447	24731	25283	16458	26349	21070	5672	19927	25627	26176	28600	20681
2520	32852	28562	-13.06	31018	32137	33551	21050	31828	28561	0	14225	37418	36814	41264	34883
2930	10083	10083	-	10666	11088	10900	11697	10506	8162	5591	7863	11489	11745	11252	10041
3500	16723	15514	-7.23	18269	17018	14488	15066	14539	17574	17480	14487	18390	2206	18867	17779
3510	20659	17969	-13.02	19019	4917	20947	22261	21562	22013	21148	12647	21657	22414	22918	4127
3520	21288	20327	-4.51	16462	16479	12828	15647	18934	23749	24572	9763	25843	25909	28885	24857
3540	8496	8496	-	7861	7958	8322	8663	8444	8592	8652	8465	8387	8398	10159	8052
5550	35008	35008	.	34341	32667	34659	33729	44447	34910	36331	36570	37096	31609	33135	30604
Correct Average		19552			18582.64					18477	16780.6		20929.27		19085.818
Indot's Average		18581		18509	17444	18834	17495	20241	19001	14451	15983	20982	19369	22825	17839
% Difference		-4.97			-6.13					-21.79	-4.75		-7.45		-6.53

The monthly volumes that are shaded are examples of apparent severe volume undercounts. Such anomalous monthly values may be due to construction zones or usual events near the count site, and should be investigated. These values, when mistakenly included in the calculations, will eventually affect the seasonal factors themselves, as can be seen in the next table.

Table 4: Seasonal Factors for Urban Principal Arterials

STAT NUM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1500	1.159	1.062	1.021	1.031	0.943	0.900	0.900	0.899	1.183	1.081	0.889	1.044
1520	1.153	1.099	1.062	1.095	0.950	0.996	1.072	1.046	0.997	1.012	0.623	1.208
1530	1.076	1.045	1.011	0.984	0.973	1.185	9.427	0.921	0.926	0.946	0.967	1.021
2500	1.067	1.047	0.995	0.982	1.049	1.066	1.014	1.004	0.978	0.952	0.875	1.006
2510	0.964	0.953	0.933	1.433	0.895	1.119	4.157	1.183	0.920	0.901	0.824	1.140
2520	1.059	1.022	0.979	1.561	1.032	1.150	-	2.309	0.878	0.892	0.796	0.942
2930	0.945	0.909	0.925	0.862	0.960	1.235	1.803	1.282	0.878	0.859	0.896	1.004
3500	0.915	0.983	1.154	1.110	1.150	0.952	0.957	1.154	0.909	7.581	0.886	0.941
3510	1.086	4.201	0.986	0.928	0.958	0.938	0.977	1.633	0.954	0.922	0.901	5.006
3520	1.293	1.292	1.659	1.360	1.124	0.896	0.866	2.180	0.824	0.822	0.737	0.856
3540	1.081	1.068	1.021	0.981	1.006	0.989	0.982	1.004	1.013	1.012	0.836	1.055
5550	1.019	1.072	1.010	1.038	0.788	1.003	0.964	0.957	0.944	1.108	1.057	1.144
Correct Average	1.068	1.313	1.063	1.114	0.986	1.036	2.102	1.298	0.950	1.507	0.857	1.364
INDOTs Average	1.023	1.234	1.017	1.061	0.942	0.991	1.827	1.228	0.911	1.428	0.820	1.278
% Difference	-4.26	-6.02	-4.30	-4.72	-4.42	-4.35	-13.09	-5.39	-4.11	-5.25	-4.30	-6.29

B.4 (iii)-b: Conclusion

Calculating the seasonal factors is a routine task, but care must be taken to make sure that the volume data used are valid. An automated procedure to assist in the review and checking of incoming data and monthly totals would be an important asset.

Suggested guidelines for quality control and quality assurance of short-term data collection

Traffic data are basic inputs for evaluation and decision making in almost all dimensions of highway planning, engineering and finance. It is therefore imperative that traffic data obtained are of excellent quality. It is usually much more expensive to go back to the field and re-do traffic measurements than to institute rigid quality control measures that would ensure that the original count carried out is satisfactory.

Quality control is the process of ensuring that good data are collected at the field. It is essentially a pre-emptive measure, focusing on equipment condition and reliability, site suitability, and proper procedures. In contrast, quality assurance is carried out after data collection, and ensures that bad data are weeded out.

Quality control and quality assurance are to some extent an integral part of INDOT's existing traffic monitoring program, but some more work apparently has to be done in this area. This may require additional staffing resources.

According to the *AASHTO Guidelines for Traffic Data Programs*, quality control and quality assurance are most effectively implemented by addressing issues through a phased approach. Such an approach, according to the *AASHTO Guidelines*, may include the following:

- A positive attitude. Positive staff attitudes toward quality control and assurance should be encouraged.
- Equipment performance standards. The *AASHTO Guidelines* maintain that traffic data collection agencies should establish goals or standards of performance before mounting any serious quality assurance effort. These standards should address issues such as equipment tolerances and failure rates, permanent counter site down-time duration, portable equipment availability, and staff productivity targets. Testing criteria for acceptance of new equipment should also be set up. The guidelines suggest that such standards should be realistic, yet challenging.
- Equipment testing schedules. Regular and random checks of the performance of existing equipment should be carried out, and the results should be evaluated against the background of the established standards. Also, new installations should be subject to frequent checks soon after start-up. The *AASHTO Guidelines* further states that in the event that intervening staff demands prevent adherence to schedules, revisions should be made immediately.
- Equipment record keeping. An effective quality assurance effort, according to the *AASHTO Guidelines*, requires careful record keeping. Records of equipment maintenance and repair would provide a basis for evaluating equipment performance, anticipating problems, developing replacement cycles, and evaluating new equipment.
- Field and shop manuals. The need for adherence to equipment performance standards, testing schedules, and record keeping should be communicated and reiterated to data collection staff. By documenting such procedures in the form of manuals, training of new staff and reinforcement of existing staff is greatly facilitated. The common base of understanding provided by manuals makes it easy for improvements and innovations to be identified.

  According to the *AASHTO Guidelines*, field and shop manuals should address, among other items, factors such as setup and installation sequences, field and shop testing and trouble shooting, record keeping requirements, performance standards and safety considerations. Videotapes may be used to complement field manuals to demonstrate field or shop techniques. Manuals should be made available to all parties involved with data collection, such as consultants hired for this purpose, and traffic data collection divisions of metropolitan planning organizations.
- Personnel resources. Staff resources are the most important element of any traffic monitoring program. The *AASHTO Guidelines* provide some principles that can lead to a motivated and dedicated workforce. These include training, encouraging workers to ask questions, and removal of administrative barriers between various staff departments. Also, it is important that staff representatives attend national and regional meetings and conferences that are relevant to traffic data collection. Such staff, upon return, should present information obtained at such meetings to an in-house audience that is likely to make use of such information.

APPENDIX H-a
SUGGESTED FORM FOR ESTIMATION OF AADT

Dates and Site Information	**Information on the Factors**
Location of 48-hr count:	*Monthly factor for seasonal group, M_h:*
Seasonal Group of road at count site	*Growthg Factor, Gh*
Date of count:	*Axle-Correction factor, A_h:*

	First 24-hour count	Second 24-hour count
Volume (i.e., number of axles), Vol		
AADT = Vol * Mh * Ah * Gh		
Total AADT		
Average AADT	= Total AADT/2 =	

This form is based on procedures described on page 3-3-10 of the Traffic Monitoring Guide (1994)

APPENDIX H-b
SUGGESTED FORM FOR ESTIMATION OF SYSTEM LEVEL STATISTICS - AVDT

a) AVDT estimation for each stratum, e.g., Rural Interstates

Vol. Group	Section ID & Location	Section AADT	Section length	Stratum Expan-sion Factor	Expanded Section DVDT	Expanded DVDT for volume group	Expanded DVDT for stratum	Expanded AVDT for stratum
		a	*b*	*c*	$d=a*b*c$	$e=sum(d)$	$f=sum(e)$	$g=365*f$
0-5000								
5000-10000								
10000-15000								

b) Total AVDT for all strata

STRATUM	AVDT

System level AVDT = SUM (AVDT)

This form is based on procedures described on page 3-3-12 of the Traffic Monitoring Guide (1994)

This form is based on procedures described on page 3-3-12 of the Traffic Monitoring Guide (1994)

APPENDIX H-c

SUGGESTED FORM FOR COMPUTATION OF GROWTH FACTORS

Seasonal Group	Station ID	AADT for year t	AADT for year t-1	Growth factor for station location, $AADT_t/AADT_{t-1}$	Growth factor for functional class
		a	*b*	$c = b/a$	$d = sum(c/n)$

The annual statewide growth factor is gievn by $G = 1/V * SUM(V_h*G_h)$

where G_h = statewide growth factor, V_h = VDT or DVDT, for the functional class h, and V = statewide VDT or DVDT (excluding local functional class)

This form is based on procedures described on page 3-3-14 of the Traffic Monitoring Guide (1994)

APPENDIX H-d

SUGGESTED FORM FOR CALCULATING PRECISION OF AADT ESTIMATES

Functional Class:

ATR Station*[1] ID #	Coverage count sites*[2]	Actual AADT i.e., from ATR*[3]	Adjusted AADT from 48-hour coverage count	Error	Coefficient of variation for coverage count	Coefficient of variation for ATR	Remarks
		a	*b*	$c = b - a$	*d*	*e*	

Average coefficient of variation of AADT estimate for entire functional class = sum(e)4 *[1]

Precision of AADT estimate for entire functional class at 100(1-x) % confidence interval

$= Z_{x/2}$ * coefficient of variation of AADT

**1, *2- For illustrative purposes, only 4 ATRs are assumed to exist for the functional class in question, and only 4 coverage counts are assumed to be associated with each ATR.*

**3- Actual AADT = Total raw count by ATR in 1 year divided by 365*

This form is based on procedures described on page .3-3-11 of the Traffic Monitoring Guide (1994)

APPENDIX H-e
SUGGESTED FORM FOR ESTIMATION OF STANDARD ERROR OF VDT ESTIMATES

Functional Class	Volume Group	Identification and description of section i	Length of Section	Daily vehicle distance traveled (DVDT) for section i	Number of HPMS universe sections in volume group	Number of HPMS sample sections in volume group	Standard error of DVDT estimate for each volume group*[1]
			a	*b*	*c*	*d*	*e*

$$e = \left\{ c(d-c)/c(c-1) * [SUMb^2 + (SUMb/SUMa)^2 * (SUMa^2) - 2*(SUMb/SUMa) * SUM(b*a)] \right\}^{0.5}$$

Estimates of the standard error of aggregate VDT estimates for HPMS strata are derived by summing the squared standard errors of the appropriate strata and taking the square root of the total. Coefficients of variation and confidence intervals can be derived by standard statistical procedures.

This form is based on procedures described on page 3-3-12 of the Traffic Monitoring Guide (1994)

APPENDIX H-f

SUGGESTED FORM FOR CALCULATING STANDARD ERROR OF GROWTH FACTORS

Seasonal Group	Number of ATR stations in seasonal group	ATR station identification #	Growth Factor for ATR station	Growth Factor for entire seasonal group	Standard error of annual growth factor for seasonal group
	a		*b*	*c*	

A rough estimate of the variability (standard error) of the statewide annual growth factor is given by: $S = (SUM[S_{hi}]^2)^{0.5}$, where S_{hi} is the growth factor for a seasonal group i. as determined from the above table.
This is only one of many possible procedures that can be used to estimate growth rates.

This form is based on procedures described on page 3-3-14 of the Traffic Monitoring Guide (1994)

SUMMARY OF RECOMMENDATIONS AND COSTING: STAFF, EQUIPMENT, AND PROCEDURES

Introduction

An assessment of INDOT's existing personnel, equipment and procedures for data collection and analysis has been made. This started with the documentation of the number and types of the current equipment, software and staff for data collection and analysis. The condition of the data collection equipment, and the capabilities of the existing hardware and software being used, were also evaluated. Various contact persons at INDOT were valuable sources in assembling the inventory and documentation of existing system components.

The existing situation has been measured against the traffic data needs of the end users and relevant federal agencies. In areas where the existing data collection and analysis efforts appear to fall short of expected or required standards, appropriate recommendations have been formulated.

The criteria against which various elements of the existing system were measured and evaluated included standards set by established bodies such as FHWA and AASHTO. Details of such standards are provided in FHWA's *Traffic Monitoring Guide* (TMG) February 1994 Edition, and AASHTO's *Guidelines for Traffic Data Programs (1990).* Other sources that were useful in the establishment of evaluation criteria include the HPMS *Field Manual* and publications by previous researchers in the field of traffic monitoring, such as *A Statistical Approach to Statewide Traffic Counting,* by Steven G. Ritchie, *Development of an Integrated Statewide Traffic Monitoring System*, by Mark E. Hallenbeck, and *Statewide Traffic Volume Studies and Precision of AADT Estimates,* by Sharma, Gulati and Rizak.

Recommendations for each Data Action Plan (DAP):

DAP B1 (Pavement Management System)

- Use to be made of portable truck-weighing equipment program recommended for HPMS in DAP B7.
- Selection of an appropriate summary statistic to give a true indication of traffic loading, independent of pavement type, for reporting to PMS.
- Review of existing continuous and coverage count programs to yield reliable and statistically valid estimates of system-level and site-specific traffic characteristics relevant to PMS. This has been carried out as part of DAPs C and B7.
- Reporting of traffic data to PMS using a relational and spatial database such as a Geographical Information System (GIS), so that traffic data can be quickly and effectively retrieved, queried, viewed and analyzed in relation to other non-traffic data of interest to the PMS.

DAP B2 (Bridge Management System)

- Use to be made of portable truck-weighing equipment program recommended for HPMS in DAP B7.
- Review of existing continuous and coverage count programs to yield reliable and statistically valid estimates of system-level and site-specific traffic characteristics relevant to BMS. This has been carried out as part of DAPs C and B7.
- Reporting of traffic data to BMS using a database such as a GIS, so that traffic data can easily be retrieved for use by BMS.

DAP B3 (Traffic Congestion Management System)

- Establishment of an administrative procedure for requesting special request counts, under the Special Needs count program. This is necessary at sites that do not fall under the existing continuous and coverage count programs, or at sites for which data offered by these programs are available but are either outdated or are of inappropriate duration or frequency.
- Use of non-intrusive traffic monitoring equipment such as video-based and radar systems for data collection at urban sites whose geometric configuration (e.g., multi-lane) or traffic flow nature (e.g., low speed and congested) preclude collection of reliable data using traditional equipment. Autoscope video sensor, manufactured by Econolite, and RTMS radar sensor, manufactured by Electronic Integrated Systems (EIS) are recommended for conduction of classification and volume counts at urban areas. A set of each type of equipment should be purchased and installed for use on an experimental basis.
- Establishment of a mechanism for regular and effective liaison between CMS and traffic data-collection divisions of Metropolitan Planning Organizations, e.g., periodic meetings directly between the two parties, inclusion of one party at periodic general meetings of the other, etc., for purposes of data sharing and comparison.
- Review of existing continuous and coverage count programs to yield reliable and statistically valid estimates of system-level and site-specific traffic characteristics relevant to CMS. This has been carried out as part of DAPs C and B7.
- Reporting of traffic data to CMS using a relational and spatial database such as a GIS, so that traffic data of interest to CMS can be quickly and effectively retrieved, queried, viewed or analyzed in relation to other non-traffic data currently being used by CMS.

DAP B4 (Safety Management System)

- Establishment of an administrative procedure for requesting special request counts. This is necessary for sites that do not fall under the existing continuous and coverage count programs, or sites for which data offered by these programs are outdated or of inappropriate duration.

- Possible use to be made of video-based traffic monitoring equipment or similar system for data collection at sites that need investigation for traffic conflicts and traffic safety.
- Establishment of a mechanism for regular and effective liaison between SMS and traffic data-collection divisions of Metropolitan Planning Organizations, e.g., monthly meetings directly between the two parties, inclusion of one party at periodic general meetings of the other, etc.

- Review of existing continuous and coverage count programs to yield reliable and statistically valid estimates of system-level and site-specific traffic characteristics relevant to SMS. This has been carried out as part of DAPs C and B7.

- Reporting of traffic data to SMS using a relational and spatial database such as a GIS, so that traffic data can be quickly queried, viewed and analyzed in relation to other non-traffic data currently being used by SMS.

DAP B7 (Highway Performance Monitoring System)

- Need for the required size of the HPMS standard sample to be updated at the end of every year, so that that needed adjustments may be implemented in the following year.
- HPMS standard sample for 1997: Using 1996 data, it was found that 127 additional standard sections are needed for various under-sized volume groups, while 1545 excess sections found in over-sized volume groups may be deleted.
- Experimental use of improved sensor technologies such as Mitron POPPS sensors (to replace road tubes) and Numetrics magnetic imaging equipment for monitoring of traffic volume and classification at high-speed HPMS sections.
- Need to continue the recently re-activated portable truck weighing activities and its possible evolution into an HPMS truck weighing program, to monitor truck weights at 60 selected sites over a three year period (the remaining 30 counts may be taken from existing permanent WIM sites). All the truck weighing sites under this program should be selected from the existing HPMS vehicle classification sample. Distribution of the number of additional truck weighing counts needed among the various road functional classes is provided in Appendix B7d(i).

  This new program, when fully implemented, would require the following resources: 8 sets of portable truck-weighing equipment, 2 pick-up trucks, and 4 full time employees.
- Review of existing continuous count program so that reasonably accurate factors can be obtained for application to short-term HPMS count data to yield reliable and statistically valid estimates of system-level and site-specific traffic characteristics. This has been carried out as part of DAP C.

- Reporting of traffic data obtained directly or indirectly from HPMS program to various end users using a relational and spatial database such as a GIS, so that each aspect of traffic data can be quickly and effectively retrieved, queried, viewed and analyzed in relation to other aspects of traffic data.

DAP C (Continuous Counts)

- Criterion C (the current INDOT grouping criterion for grouping traffic volume data) should be maintained as a basis for grouping volume-measuring ATR sites, calculating adjustment factors and annual checking of adequacy of sample size for volume-measuring ATRs in the various seasonal groups. This criterion does not call for any additional sites.
- Criterion H (based on regional and functional classes) should be used for grouping vehicle classification sites. The use of this criterion and a precision of "99-10" calls for about 60 additional vehicle-classification ATR sites. The distribution of these additional ATR sites among the seasonal groups, as well as their geographical locations, have been provided in the relevant section of this report. In the choice of new ATR sites from potential locations, emphasis was placed on the possible upgrading of existing volume-measuring Telemetry sites to vehicle-classification status, rather than establishing completely new classification ATR sites.
- Selection of Criterion G (based on functional class only) for truck weight data. With a reliability requirement of "90-10", this criterion requires 3 additional truck-weighing ATR sites. The distribution of these additional ATR sites among the various seasonal groups of Criterion G, as well as their geographical locations, have been provided in the relevant section of this report. Rather than set up new sites, emphasis has been placed on the upgrading of existing volume-measuring Telemetry sites, wherever possible, to carry out truck-weighing in addition to traffic volumes.
- Existing staff for maintaining ATR sites should be increased by 2 field technicians, in wake of anticipated increases in scope of data collection after implementation of ATR-upgrading and new ATR recommendations. Also, a new total staff strength of four ATR field technicians would make it possible for INDOT to carry out much-needed ATR calibration and performance checks on a periodic basis.

DAP D1 (Short-Term Counts- Equipment Adequacy and Accuracy)

- Current performance deviation checks and calibration tests by INDOT field staff and equipment manufacturer's representatives respectively, for short-term equipment are generally adequate and should be continued.
- Experimental use of improved sensor technologies at some locations such as Mitron's POPPS sensors (to replace road tubes) and Numetric's magnetic imaging equipment for monitoring of traffic volume and classification at high-speed and other problematic coverage count locations.

- INDOT's entire procedures currently used for field testing, data collection and analysis of short-term counts should be documented. Such documentation may be carried out based on the findings of this study, in DAPs D1, and H1/H2.
- INDOT should establish a revised coverage count program that would place emphasis on roads on the National Highway System and roads in high growth counties.
- Development of the current nascent portable truck weighing program for short-term monitoring of truck weights, for possible future needs of HPMS, and present needs of PMS and other end-users. Details of this activity are provided in DAP B7.

DAP D2 (Vehicle Classification Activities on the National Highway System)

- Upgrade of Telemetry sites on the NHS network to vehicle classification capabilities.
- Implementation of new frequency of coverage counts (these include classification) for NHS roads that would ensure compliance to the minimum 3-year cycle length. Details of this are provided in DAP D1.
- INDOT should ensure that, over a three-year cycle, vehicle classification counts are carried out on the NHS segments such as I-465 at which abnormal traffic conditions prevent the use of traditional short-term coverage count classification equipment, such as I-465. This would involve the use of non-intrusive technology such as radar or video. Details of this are provided in DAP C.

DAP H1/H2 (Short-Term Counts-Data Collection and Analysis Processes and Procedures)

- Establishment of an administrative procedure for special request short-term counts. This is necessary for sites that do not fall under the existing coverage count programs, or sites for which data offered by these programs are outdated or are of inappropriate duration.
- Documentation of field procedures utilized in data collection, and office procedures for calculation of various adjustment factors and annualized statistics.
- Regular, sustained, and critical editing of short-term traffic data for error detection and diagnosis, and immediate feedback, if necessary, to field staff for appropriate remedial action. Such an exercise would require one (1) experienced office-based full-time Traffic Data Analyst, equipped with appropriate computer hardware and software, to...
    - recognize occurrence of value repetition indicative of machine malfunction.
    - use directional distribution of traffic to edit traffic data.
    - use nested counts to compare measured values of traffic characteristics, e.g., compare traffic volumes measured by short-term counts at a specified location to volumes measured by any WIM

equipment located at or reasonably close to that location.
- keep a record of atypical traffic and special events at locations for which measured traffic data might otherwise be mislabeled as erroneous.
- edit data in both temporal and spatial contexts. The use of a GIS is recommended to facilitate data editing in the latter context.

- Avoidance of the following pitfalls in the calculation of adjustment factors:
  - exclusion of zero values (default values to represent missing data) in the calculation of average monthly values of traffic characteristics such as ADT.
  - identification and exclusion of anomalous data (generated by malfunctioning equipment) in the calculation of average monthly values of traffic characteristics.

DAP G: Database improvement

- Acquisition and installation of TRADAS 2 database system, and an appropriate GIS software. 2 FTEs will be needed to manage these systems.
- Acquisition of new computers (1 mid-range computer, 1 work station, and 3 personal computers) to improve existing network architecture and thus enhance management of the large amounts of data expected after implementation of recommendations for various count activities.
- Continued retention of traffic data on optical disks for a minimum period of 10 years, for all count types.
- Use of GIS to assist in data management.

General

- INDOT should continue to participate actively in federal and inter-state activities the involve or include traffic monitoring such as the Transport Research Bureau (TRB) and Institute of Transportation Engineers (ITE) annual conferences, and the National Data Acquisition Conference (NATDAC), which is held every two years. Such forums provide INDOT TMS personnel an opportunity to share their experiences with other states, and to learn about new methods and equipment for collection and for analysis of traffic data.
- INDOT should also continue the practice of holding workshops on various aspects of traffic monitoring for the benefit of MPOs and other agencies involved in collection and management of traffic data. This would ensure that MPOs carry out data collection and management in a uniform and correct manner.

SUMMARY OF RECOMMENDATIONS

Recommendation	Count program or management system to benefit from recommendation	Remarks (additional resources, etc.)
A: Data Collection		
1. Development of portable WIM program	PMS, BMS,HPMS	8 sets of equipment 4 field technicians 1 van and accessories
2. Establishment of administrative procedure for special request counts	PMS, CMS, SMS, BMS	
3. Acquisition of equipment that use non-intrusive technology for multi-lane, congested, and low-speed sections and intersections	CMS, SMS, VCA-NHS	2 sets of equipment and accessories (Autoscope 2004, and RTMS) 1 van or pick-up truck 2 field technicians
4. Establishment of 56 additional sites to carry out continuous classification counts	Classification element of Continuous Count program	Emphasis should be placed on upgrading existing Telemetry sites to classification status. After upgrading, 2 additional field staff would be required to assist in maintenance of improved equipment.
5. Establishment of about 3 additional sites to carry out continuous truck weight counts	Truck-weighing element of Continuous Count program	Emphasis should be placed on upgrading existing Telemetry sites to truck-weighing capabilities
6. Establishment of a systematic program for calibration and performance-checking of all ATRs	Traffic volume, classification, and truck-weighing elements of Continuous Count program	2 ATR field technicians
7. New program for short-term volume and classification coverage counts for emphasis on NHS and high-growth counties	Coverage counts (CFM, HPMS) and VCA-NHS	5 vans and accessories 5coverage-count field technicians
8. Purchase, installation and experimental use of improved sensors and magnetic imaging equipment for short-term volume and classification coverage counts at problematic (e.g. high speed) count locations	Coverage counts (HPMS, CFM)	10 Mitron POPPS sensors 20 Numetrics HiStar NC-90As

SUMMARY OF RECOMMENDATIONS (cont'd)

Recommendation	Count program or management system to benefit from recommendation	Remarks
B: Data Processing, Analysis, and Reporting		
1. Documentation of current procedures for data collection and analysis	All count programs and management systems	Has been carried out in this study. Based on this and other in-house sources, INDOT may publish formal document for reference purposes and for distribution to MPOs
2. Continued regular, sustained and critical editing of short-term and ATR-generated traffic data	All count programs and management systems	
3. Continued adherence to recommended procedures in calculation of adjustment factors and summarized statistics	All count programs and management systems	
4. Continued calibration and performance deviation checks for short-term monitoring equipment	Short-term counts	
5. Annual review of the size of the HPMS standard sample, volume sample and classification sample to ensure compliance with precision requirements	HPMS	Pending outcome of FHWA's strategic re-assessment of the HPMS program
6. Upgrading of current database system to cater for increased data needs, new reporting formats and to facilitate sorting and querying operations	All count programs and management systems	TRADAS 2 recommended 1 traffic data analyst needed
7. Establishment of a GIS to enable traffic data to be reported and viewed in a spatial context	All count programs and management systems	INDOT to review alternative GIS systems for selection. Establishment of entire GIS system may be given out on contract.
8. Acquisition of software to process and analyze data from portable WIM equipment	HPMS, PMS, BMS	1 GIS specialist needed to maintain and update GIS system after its establishment
9. Acquisition of software to process and analyze data from equipment that use non-intrusive technologies	CMS, VCA-NHS	Already available as part of entire package that accompanies such equipment
10. Acquisition of new computers to improve existing data handling capabilities (to be used with TRADAS and appropriate GIS software)	All count programs and management systems	1 mid-range, 1 server, and 3 personal computers

SUMMARY OF RECOMMENDATIONS (cont'd)

Recommendation	Count program or management system to benefit from recommendation	Remarks
C. General		
1. Effective liaison between management systems and data collection divisions of MPOs through periodic meetings, workshops, etc.	All count programs and management systems	
2. Continued implementation of quality control and quality assurance measures throughout the entire cycle of data collection, data processing and analysis, and data reporting	All count programs and management systems	
3. Continued active involvement in national and inter-state conferences, meetings and workshops on traffic monitoring activities	All count programs and management systems	

SUMMARY OF COSTS

Description	Personnel (per annum)	Equipment	Remarks
1. Development of portable WIM program	1 data collection supervisor, @$35,000 =$35,000*[1] 3 data collection technicians @30,000*[1] = $90,000	8 sets of equipment @$20,000 = $160,000 1 van, with accessories @ $35,000 = $35,000	
2. Acquisition and use of equipment that use non-intrusive technologies	2 data collection technicians @30,000*[1] = $60,000	1 set of Autoscope 2004 @$24,000 = $24,000 1 set of RTMS @$17,000 = $17,000	
3a. Upgrading of a selected number of existing Telemetry sites to classification capabilities, and installation of new sites	Current staff may not have the expertise for such upgrades. This may be given out on contract, and handed over to existing INDOT field staff after completion of the upgrading exercise, for maintenance	Provision and installation of equipment and accessories for upgrades may be given out on contract Current rates are approx. $50,000 per equipment at each location	
3b. Installation of new classification ATR equipment at new sites	same as above	Current rates are not yet available	
4a. Upgrading of 1existing Telemetry site to truck-weighing capabilities	Current staff may not have the expertise for such upgrades. This may be given out on contract, and handed over to existing INDOT field staff after completion of the upgrading exercise, for maintenance	Equipment and accessories required for the upgrades may be given out as part of the upgrade contract	Current rates for upgrading telemetry ATRs stations to truck-weighing status were not available at time of reporting
4b. Installation of new truck-weighing ATR equipment at new sites	same as above	2 new permanent WIM equipment @ $170,895 = $341,790	4-lane Single Load Cell WIM equipment

SUMMARY OF COSTS (cont'd)

Description	Personnel (per annum)	Equipment	Remarks
5. Purchase of new sensors to replace road tubes at certain high-speed locations, and experimental use of magnetic imaging equipment for coverage counts at similar problematic locations		a) 20 *Numetrics HiStar NC-90As* @ $950 = $19,000 2 HiStar portable486 Laptop computers @ $2995 = $5990 20 mounting straps and protective covers @235 = $4700 b) 10 *Mitron POPPS sensors* @ $399= $3990 5 POPPS universal adapters @ 399= $1995	
6. Implementation of new schedule for coverage counts	5 field technicians @ $30,000*[1] = $150,000 per annum	34 additional counters. Minimum stock of 3168 standard-length road tubes per year	5 additional vans and accessories @$45,000*[2] = $185,000
6. Improvement of existing hardware architecture and database systems (TRADAS and GIS) to manage increased load of traffic data at various stages	1 data analyst @ $35,000*[1] = $35,000 1 GIS specialist @35,000*[1] = $35,000	1 mid-range computer (IBM 520) including accessories @ $20,000 = $20,000 1 computer work-station (IBM MMX) including accessories @ $9,000 = $9,000 3 personal computers (IBM PC250) including accessories @ $3,000 = $9,000	<u>Software costs</u> TRADAS 2: $30,000 per annum GIS software: price not available at time of reporting

*1: Source: Careerpath.com, JobTrack.com, and Occ.com (World Wide Web). Excludes fringe benefits and other administrative overheads

*2: Tentative cost indicated.

APPENDICES TO MAIN REPORT

CONTENTS OF THE APPENDIX

APPENDIX 1

EXISTING EQUIPMENT FOR COLLECTION OF TRAFFIC DATA (as of 12/15/97)

a) Permanently installed ATRs (WIMs and Telemetry Stations)

Serial Number	Station Nr, Highway, (near...)	Equipment type	Manufacturer	Year installed	Remarks, etc.
0	INDOT central office	IRD central control station	IRD	1991	
1	5240 US-52 (Fowler)	WIM bending plate	IRD	1991	SHRP site Single bending plate in 1 of 2 lanes, No NB traffic sensors
2	5450 I-65 (Lafayette)	Piezo WIM Sensors	IRD	1991	HPMS segment 000065174130 SHRP site 18518 Piezo sensors installed in NB and SB lanes in September 1996
3	5130 I-74 (Covington)	Piezo WIM sensors	IRD	1991	HPMS segment 000074000000 Piezo sensors installed in June 1997
4	5440 I-70 (Terre Haute)	WIM bending plates/ Piezo WIM sensors	IRD	1991	HPMS segment 000070007220 Formerly Telemetry station # 2430. Single bending plates originally in 2 of 4 lanes. WB bending plate removed in 1996, and replaced with Piezo sensors in June 1997
5	4150 I-69 (Angola)	SLC WIM in all four lanes	IRD	1991	HPMS segment 000069128720 Speed site FR 65RI07-SB SLC WIM installed in August 1997 under pavement warranty
6	4270 US-24 (Wabash)	WIM bending plate	IRD	1991	WIM installed on WB lane
7	4140 I-69 (Marion)	WIM bending plate (SB)	IRD	1991	HPMS segment 00069065040 SHRP site 189020 Speed site FR65RI04-SB
8	4280 US-27 (Fort Wayne)	WIM bending plate	IRD	1991	SHRP site 182008 Speed site NF55RA11-SE WIM installed on SB lane
9	5140 I-70 (Richmond)	Piezo WIM sensors	IRD	1991	HPMS segment 000070150670 Piezo sensors installed in July 1997
10	5460 I-465 (Indianapolis)	Piezo WIM sensors	IRD	1991	HPMS segment 000465009320 Speed site FR55UI06-SB Bending plates in 4 of 6 lanes replaced with Piezo sensors in June 1996
11	5470 I-65 (Southport)	Piezo WIM sensors	IRD	1991	HPMS segment 00065100650 SHRP site 185022 Bending plates in both 2 NB lanes replaced with Piezo sensors in summer 1994

APPENDIX 1 (cont'd)

EXISTING EQUIPMENT FOR COLLECTION OF TRAFFIC DATA

a) Permanently installed ATRs (WIMs and Telemetry Stations) cont'd

Serial Number	Station Nr, Highway, (near…)	Equipment type	Manufacturer	Year installed	Remarks, etc.
12	5480 I-465 (Indianapolis)	Piezo WIM sensors	IRD	1991	HPMS segment 000465041050 Single bending plates in 4 of 6 lanes replaced with Piezo sensors in August 1996
13	5270 SR-332 (Indianapolis)	WIM bending plate	IRD	1991	HPMS segment 180100350000 SHRP site 183030 Single bending plate in 2 of 4 lanes
14	5260 SR-37 (Noblesville)	WIM bending plate	IRD	1991	HPMS segment 290045765000 SHRP site182009 Single bending plate in 1 of 4 lanes. Site shifted to new location
15	5550 US-31 (Carmel)	WIM bending plate	IRD	1991	HPMS segment 290025650000 SHRP site 184021 Single bending plate in 1 of 4 lanes
16	4130 I-94 (Mich. City)	Single Load Cell WIM	IRD	1991	HPMS segment 000094027980 Upgraded from Telemetry station # 1120
17	4250 SR-2 (LaPorte)	WIM bending plate	IRD	1991	HPMS segment 460358825000 SHRP site 185528 WIM installed on EB lane
18	4440 I-80 (Gary)	Piezo WIM sensors	IRD	1991	HPMS segment 000080004910 Piezo sensors installed in all 6 lanes by October 1997
19	4260 US-31 (Plymouth)	WIM bending plate	IRD	1991	HPMS segment 500027702000 SHRP site 183003 Upgraded from Telemetry station # 1230 WIM installed on NB lane
20	4240 SR-49 (Valpo)	WIM bending plate	IRD	1991	Bending plates removed in July 1996, but not replaced due to poor pavement condition
21	5250 SR-37 (Bloomington)	WIM bending plate	IRD	1991	HPMS segment 530002602000 Speed site NF55RA24-SE Single bending plate in 1 of 4 lanes
22	6170 I-74 (W. Harrison)	WIM bending plate	IRD	1991	HPMS segment 00074168890 Speed site FR65RI06-EB Single bending plate in 2 of 4 lanes 2 bending plate vaults installed in summer 1996
23	6290 US-50 (Versailles)	Piezo WIM sensors		1991	HPMS segment 690050022000 Single bending plate in 1 of 2 lanes, but replaced with Piezo sensors in both lanes August 1996

APPENDIX 1 (cont'd)

EXISTING EQUIPMENT FOR COLLECTION OF TRAFFIC DATA

a) Permanently installed ATRs (WIMs and Telemetry Stations) cont'd

Serial #	Station Nr., Highway, (near...)	Equipment type	Manufacturer	Year installed	Remarks, etc.
24	6420 I-65 (Clarksville)	Piezo WIM sensors	IRD	1991	HPMS segment 000065003820 Piezo sensors in both lanes that replaced bending plates were destroyed during road construction in summer 1997.
25	6160 I-64 (New Albany)	WIM bending plate	IRD	1991	HPMS segment 000064113840 Single bending plate in 2 of 4 lanes 2 bending plate vaults installed in August 1995
26	6280 US-50 (Washington)	WIM bending plate	IRD	1991	HPMS segment 140400002000 Single bending plate in 1 of 2 lanes
27	6140 I-64 (Evansville)	WIM bending plate	IRD	1991	HPMS segment 000064027460 SHRP site 186012 Speed site FR65RI05-EB Single bending plate in 2 of 4 lanes 2 bending plate vaults installed in summer 1996
28	6250 SR-62 (Mt. Vernon)	WIM bending plate	IRD	1991	SHRP site 183031 Single bending plate in 1 of 4 lanes
29	6260 SR-66 (Evansville)	WIM bending plate	IRD	1991	SHRP site 185043 Single bending plate in 1 of 4 lanes
30	6270 SR-66 (Hatfield)	WIM bending plate	IRD	1991	HPMS segment 40721000000 SHRP site 181037 Speed site NF55RA29-WB Single bending plate in 1 of 4 lanes
31	6150 I-64 (Dale)	WIM bending plate	IRD	1991	HPMS segment 0000640664460 SHRP site 181028 Single bending plate in EB lane Bending plate vault installed in summer 1996
32	6130 I-164 (Evansville)	WIM bending plate	IRD	1991	HPMS segment 000164000820 Speed site FR55UI08-WB Single bending plate in 1 of 4 lanes
33	4110 I-65 (Rensselaer)	Piezo WIM sensors in SB lane	IRD	1993	HPMS segment 000065219940 Bending plates removed in both SB and NB lanes

APPENDIX 1 (cont'd)

EXISTING EQUIPMENT FOR COLLECTION OF TRAFFIC DATA

a) Permanently installed ATRs (WIMs and Telemetry Stations) cont'd

Serial #	Station Nr., Highway, (near…)	Equipment type	Manufacturer	Year installed	Remarks, etc.
34	5110 I-70 (Greenfield)	Single Load Cell WIM (all 4 lanes)		1996	HPMS segment 000070104560 Speed site FR65RI01-EB Upgraded from Tel 2110 in 1996
35	2230 US-231 (Romney)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 790080002000
36	2340 US-136 (Crawfordsvill e)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
37	2510 US-52 (Lafayette	Telemetry inductive loop	StreeterAmet & Richardson	1985	
38	2100 I-70 (Brazil)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 000070022570
39	2300 SR-42 (Stearville)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 11011602002
40	2520 US-41 (TerreHaute)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 84003410100
41	1100 I-69 (Huntington)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 000069071550
42	1310 SR-101 (Decatur)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 010373002000 Speed site NF55RO13-SB
43	1320 SR-124 (Bluffton)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
44	1420 I-69 (Ft Wayne)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 000069109290
45	1510 SR-37 (Ft. Wayne)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 020173152000
46	1220 US-6 (Goshen)	Telemetry inductive loop	StreeterAmet & Richardson	1985	

APPENDIX 1 (cont'd)
EXISTING EQUIPMENT FOR COLLECTION OF TRAFFIC DATA

a) Permanently installed ATRs (WIMs and Telemetry Stations) cont'd

Serial #	Station Nr, Highway, (near…)	Equipment type	Manufacturer	Year installed	Remarks, etc.
47	1330 SR-120 (Middlebury)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
48	1520 US-33 (Elkhart)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 200212202000
49	1530 SR-15 (Warsaw)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 430023352001
50	2500 SR-9 (Anderson)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 480016682001
51	2310 US-40 (Greenfield)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
52	2320 SR-44 (Rushville)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
53	2400 I-65 (In' polis)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 4903000002001
54	2420 I-465 (In'polis)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 000465045270 Speed site FR55UI01-NB
55	2330 SR-1 (Farmland)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
56	2530 SR-3 (Muncie)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
57	1200 US-41 (New Paris)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 200025800000 Speed site NF55RA10-EB
58	1400 I-80 (Gary)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 000080012930 Speed site FR55UI02-WB
59	1410 I-65 (Merillville)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 000065249560
60	1300 SR-17 (Logansport)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
61	2210 US-421 (Monticello)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 080098002001 Speed site NF55RA07-NB

APPENDIX 1 (cont'd)

EXISTING EQUIPMENT FOR COLLECTION OF TRAFFIC DATA

a) Permanently installed ATRs (WIMs and Telemetry Stations) cont'd

Serial #	Station Nr, Highway, (near…)	Equipment type	Manufacturer	Year installed	Remarks, etc.
62	2220 US-24 (Wolcott)	Telemetry inductive loop	StreeterAmet& Richardson	1985	
63	1210 US-30 (Valpo)	Telemetry inductive loop	StreeterAmet& Richardson	1985	HPMS segment 647045902000 Speed site NF55RA06EB
64	1500 US-20 (Mich. City)	Telemetry inductive loop	StreeterAmet& Richardson	1985	
65	3100 I-74 (Batesville)	Telemetry inductive loop	StreeterAmet& Richardson	1985	HPMS segment 000074148920
66	3210 US-50 (Aurora)	Telemetry inductive loop	StreeterAmet& Richardson	1985	HPMS segment 150109002000 Speed site NF55RA09-WB
67	2200 SR-67 (Martinsville)	Telemetry inductive loop	StreeterAmet& Richardson	1985	
68	2410 SR-37 (In'polis)	Telemetry inductive loop	StreeterAmet& Richardson	1985	
69	2540 SR-37 (Monroe)	Telemetry inductive loop	StreeterAmet& Richardson	1985	HPMS segment 530014002000
70	3400 I-265 NewAlbany	Telemetry inductive loop	StreeterAmet& Richardson	1985	HPMS segment 000265000840
71	3410 I-65 (Clarksville)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 000065003820 Speed site FR55UI04-SB
72	3500 SR-62 New Albany	Telemetry inductive loop	StreeterAmet & Richardson	1985	SR-62 is now Spring Street
73	3220 US-421 (Versailles)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
74	3540 US-421 (Madison)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
75	3110 I-65 (Seymour)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 000065041080 Speed site FR 65RI08-SB

APPENDIX 1 (cont'd)
EXISTING EQUIPMENT FOR COLLECTION OF TRAFFIC DATA

a) Permanently installed ATRs (WIMs and Telemetry Stations) cont'd

Serial Number	Station Nr, Highway, (near…)	Equipment type	Manufacturer	Year installed	Remarks, etc.
76	3230 SR-56 (Little York)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 880126002000
77	3320 SR-160 (Henryville)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
78	3200 SR-56 (Haysville)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 190135002000
79	3330 SR-61 (Spurgeon)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
80	3530 SR-162 (Jasper)	Telemetry inductive loop	StreeterAmet& Richardson	1985	
81	3240 US-41 (Staser)	Telemetry inductive loop	StreeterAmet& Richardson	1985	HPMS segment 820024452000 Speed siteNF55RA17-NB
82	3510 SR-66 (Evansville)	Telemetry inductive loop	StreeterAmet& Richardson	1985	HPMS segment 82011897200
83	3520 US-41 (Evansville)	Telemetry inductive loop	StreeterAmet& Richardson	1985	HPMS segment 820013952000
84	3300 SR-550 (Bruceville)	Telemetry inductive loop	StreeterAmet& Richardson	1985	
85	3340 SR-56 (Hazleton)	Telemetry inductive loop	StreeterAmet& Richardson	1985	
86	3120 I-65 (Dale)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 000064063720 Speed site FR 65RI02-WB
87	3310 SR-64 (English)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
88	1430 US-20/31 (South Bend)	Telemetry inductive loop	StreeterAmet & Richardson	1985	HPMS segment 7100 82002000 Speed site FR55UO05NB
89	2920 High St. 819 (Bloomington)	Telemetry inductive loop	StreeterAmet & Richardson	1985	

APPENDIX 1 (cont'd)
EXISTING EQUIPMENT FOR COLLECTION OF TRAFFIC DATA

a) Permanently installed ATRs (WIMs and Telemetry Stations) cont'd

Serial #	Station Nr, Highway, (near...)	Equipment type	Manufacturer	Year installed	Remarks, reliability measures, etc.
90	2930 1512E3rd St. (Bloomington)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
91	2910 495East Winslow (Bloomington)	Telemetry inductive loop	StreeterAmet & Richardson	1985	
92	2940 113 North Indiana (Bloomington)	Telemetry inductive loop	StreeterAmet & Richardson	1985	

Total number of WIM sites = 34 *[1]
Total number of Telemetry sites = 58

*1: As of December 1997, there are 35 WIM sites: INDOT has indicated that a new site, WIM 5120 with SLC (Single Load Cell) in all 4 lanes, that was installed in summer 1997 near Edinburgh on I-65, had just been made operational.

APPENDIX 1 (cont'd)
EXISTING EQUIPMENT FOR COLLECTION OF TRAFFIC DATA

b) Portable equipment used at temporary sites by INDOT (as of 15 October 1997)

Manufacturer	Model	Type	Quantity	Purchase date	Current condition	Usage
Peek Traffic	TrafiCOMP II Model 141	Counter/ classifier	34	1984	Fair	Stored
Peek Traffic	TrafiCOMP III Model 241-2RT	Counter/ classifier	60	1987/1988	Good *1	Weekly
Golden River*2	Archer Model 6400	Counter/ classifier	37	1988	Fair	Several times a year
Peek Traffic	TrafiCOMP III Model 241-2RT	Counter/ classifier	106	1989/1994	Fair	Weekly
Peek Traffic	TrafiCOMP III Model: 241-4RT-8A-8P-8L	Counter/ classifier	18	1992/1994	Good	Several times a year
Peek Traffic	TrafiCOMP III Model 241-EZ	Counter/ classifier	86	1995/1996	Good	Weekly

Total = 351
Effective total =314 (excluding Golden River equipment)

*1- Recently refurbished and upgraded to 241-EZ
*2- This equipment classifies vehicles by length, not by axle configuration. Also, the format of its print-outs are not as desired. Therefore, this equipment is not used for 48-hour counts.

APPENDIX 1 (cont'd)
EXISTING EQUIPMENT FOR COLLECTION OF TRAFFIC DATA

c) Portable equipment used at temporary sites by the MPOs (as on 10/1/97)

Metropolitan Planning Organization (MPO)	Data collection equipment
1. The Indianapolis Metropolitan Planning Organization	A total of 68 counters, consisting of the following models: GK-5000, GK-6000, and Numetrics NC-90
2. The Madison County Council of Governments (MCCOG)	4 Golden River Archer 6400 counter/classifiers
3. City of Bloomington Planning Department	6 TRAX II counters/classifiers 3 Numetrics NC-90a counters/classifiers 1 Jamar IMC IV
4. Kentuckiana Regional Planning and Development Agency (KIPDA)	6 Numetrics NC-90A counter/classifiers 1 GK-5000 4 Count boards of unspecified make 1 Jamar DB-100
5. The Area Plan Commission of Tippecanoe County (APC)	Relies on City and County count programs
6. Michiana Area Council of Governments (MACOG)	A total of 58 counters/classifiers of the following models: 32 Numetrics NC-90A 14 GK-5000 8 GK-4000 4 GK-6000
7. Kokomo-Howard County Government Coordinating Council (GCC)	4 GK-5000 Counters 8 GK-5000 and Mitron MSC 3000 belong to the city and county respectively
8. Northwestern Indiana Regional Planning Commission (NIRPC)	12 counters of unspecified make
9. Muncie Area Planning Commission	4 ADR 100 model 1 Peek TraffiComp 241 Counters
10. Northern Indiana Regional Coordinating Council (NIRCC)	22 Peek TraffiComp 241 Counters 8 counters of uncertain brand, 101B model
11. West Central Indiana Economic Development District (WCIEDD)	6 counters of TrafficTally 501 model

Total number of counters/classifiers = 217
This inventory excludes equipment used by the MPO responsible for the Evansville area.

APPENDIX 2

EXISTING PERSONNEL FOR COLLECTION OF TRAFFIC DATA

a) INDOT staff responsible for data collection (as on 15 December 1997)

JOB TITLE	NUMBER	DUTIES	REMARKS
Traffic Data Collection Supervisor	1	• Coordination of entire data collection activity • Overall supervision, and provision of support and logistics for data collection • Liaison between office-based data collection technicians and field-based staff • Regular inventory of existing data-collection equipment	• Is on 24-hour call in case of emergencies
Traffic Data Collection Coordinator	1	• Liaison between office-based data collection technicians and field-based staff • Receipt and review of WIM data directly from field equipment	Office-based. Shuttles between field and office.
Field Technicians	7	• Collection of field data for Coverage counts	
Electronics Technicians	2	• Repair, maintenance and calibration of WIM equipment • Upkeep of WIM and Telemetry sites	Field-based (mobile)

Notes: 1) A&F Engineering, and Presnell & Associates, are consultants hired by INDOT to assist with the Coverage Count data collection exercise.

2) There are no in-house personnel for repair and maintenance of equipment used for the Coverage Counts. This equipment is maintained by the manufacturer's representative.

3) All traffic data referred to in this table is with regard to road traffic unless otherwise indicated.

APPENDIX 2 (cont'd)
EXISTING PERSONNEL FOR COLLECTION OF TRAFFIC DATA

c) MPO staff responsible for data collection using portable equipment at temporary sites

METROPOLITAN PLANNING ORGANIZATION (MPO)	TRAFFIC DATA COLLECTION STAFF (AS ON OCTOBER 1, 1997)
1. The Indianapolis Metropolitan Planning Organization	2 traffic data collection technicians
2. The Madison County Council of Governments (MCCOG)	Not indicated
3. City of Bloomington Planning Department	1 traffic data collection supervisor 3 traffic data collection technicians seconded by the City Engineering and County Highway Departments.
4. Kentuckiana Regional Planning and Development Agency (KIPDA)	3 traffic data collection staff, also responsible for data analysis and equipment maintenance
5. The Area Plan Commission of Tippecanoe County (APC)	None. This MPO is not responsible for the data collection aspect of the traffic data program. The Engineering departments of the constituent cities are responsible.
6. Michiana Area Council of Governments (MACOG)	1 traffic data collection technician 1 support technician
7. Kokomo-Howard County Government Coordinating Council (GCC)	None. This MPO is not responsible for the data collection aspect of the traffic data program. This activity is carried out by the Engineering departments of the constituent cities as part of an agreement with the city and county.
8. Northwestern Indiana Regional Planning Commission (NIRPC)	1 traffic data collection technician (summer only)
9. Muncie Area Planning Commission	3 traffic data collection technicians, out of which 2 are also responsible for data analysis
10. Northern Indiana Regional Coordinating Council (NIRCC)	1 full-time traffic data collection technician 1 part-time traffic data collection technician
11. West Central Indiana Economic Development District (WCIEDD)	2 staff for both data collection and data analysis

TOTAL STAFF FOR DATA COLLECTION IN ALL MPOS = **19**

This list excludes data collection staff of the MPO responsible for the Evansville area.

APPENDIX 3

EXISTING HARDWARE AND SOFTWARE FOR PROCESSING AND ANALYSIS OF TRAFFIC DATA

a) Hardware and software used at INDOT Central Office (as on 15 December 1997).

WORK ACTIVITY	HARDWARE/SOFTWARE USED	REMARKS
1a) Automatic receipt (polling) of WIM data from field at 'processing center'	• 9600-baud modem • IRD Software (includes ProComm) • IRD Central Control Station	Office-based (INDOT, Indianapolis)
1b) Automatic receipt (polling) of telemetry data from field, at 'processing center'	• Streeter Richardson Telac 560 Central Control Station (IBM PC-AT) • 1200-baud modem	Office-based (INDOT, Indianapolis)
1c) Printing and checking of collected coverage count data. Copying of checked data on floppy disk	• Portable PC's and printers (7No) • TDP Software • Lotus 2.2	Site-based
2a) Polling of raw WIM and Telemetry data received from the field stations	• IBM PC 486 • IRD Software 7.4.4	Office-based (INDOT, Indianapolis)
2b i.) Checking of Coverage count data on disk for validity and printouts	• Desktop PC's (2 No) • Portable PC's (2 No) • TDP Software • Lotus 2.2	Site-based
2b ii.) Review and compilation of checksheets, and validation, for Coverage count data.	• IBM PC's 486 (2 No) • Lotus 2.2	Office-based (INDOT, Indianapolis)
2c iii.) Evaluation and application of excess axle adjustments	• IBM PC's 486	Office-based (INDOT, Indianapolis)
3. Conversion of traffic volume data from WIM, Telemetry, and Coverage counts into common format for input into mainframe	• IBM PC 486 • Lotus 2.2	Same equipment as that used in polling raw data
4. Annualisation of 48 hour counts using adjustment factors, and generation of AADT's	• IBM 5620 Mainframe	Office-based (INDOT, Indianapolis)
5. Data verification and breakpoint analysis in traffic, for creation of flow maps	• IBM PC 486	Office-based (INDOT, Indianapolis)
6. Annual update of AADT's in Road Inventory file	• IBM PC 486	Office-based (INDOT, Indianapolis)
7. Generation of traffic volume reports, saving of data, and storage of reports on optical disks	• Optical disks	Office-based (INDOT, Indianapolis)

APPENDIX 3 (cont'd)

EXISTING HARDWARE AND SOFTWARE
FOR PROCESSING AND ANALYSIS OF TRAFFIC DATA

b) Hardware and software used at the offices of the various MPOs. (as on 15 December 1997).

METROPOLITAN PLANNING ORGANIZATION (MPO)	HARDWARE AND SOFTWARE
1. The Indianapolis Metropolitan Planning Organization	2 Zenith 486 computers Histar, TAS, TMCPRO, VOLPRO and IMC software Data retention: Computer hard drive, floppy disks, hard copy
2. The Madison County Council of Governments (MCCOG)	2 Gateway Pentium computers Archanal/Stratgraf 4.1, PC plus, TransCAD and dBase 4.5 Data retention: traffic data are stored in hard drive, on floppies and on print-outs in a map form using software
3. City of Bloomington Planning Department	4 486 computers, model and brand not specified, that use standard processing software Counters use Histar LP 5.4 software
4. Kentuckiana Regional Planning and Development Agency (KIPDA)	1 IBM-compatible 486 computer, using standard software such as Excel and Access 1 laptop computer that uses Petra LT and Histar to download data from field equipment
5. The Area Plan Commission of Tippecanoe County (APC)	2 Gateway 486 computers, scheduled for upgrading by 1998. Data are retained on hard drive, floppies and hard copy in spreadsheet format.
6. Michiana Area Council of Governments (MACOG)	2 computers (1 desktop and 1 laptop) used. TAS Plus software used to analyze data from GK counters, and HDM Histar used for Numetrics data
7. Kokomo-Howard County Government Coordinating Council (GCC)	1 IBM 386 computer
8. Northwestern Indiana Regional Planning Commission (NIRPC)	2 386 PCs are used with Paradox and QuattroPro software
9. Muncie Area Planning Commission	2 Sun computers 3 Microcomputers (Dell, Ambra, and Swan) VISA and Q&A software used for analysis and processing
10. Northern Indiana Regional Coordinating Council (NIRCC)	1 IBM-compatible 486 computer 1 IBM notebook computer TrafiComp 241 and Lotus 1-2-3 are used for analysis
11. West Central Indiana Economic Development District (WCIEDD)	1 Packard Bell Pentium 60 1 IBM-compatible 486-33 Paradox, Lotus for Windows, Harvard Graphics and ForecastPro

This list excludes equipment used by the MPO responsible for the Evansville area.

APPENDIX 4
EXISTING PERSONNEL FOR ANALYSIS AND PROCESSING OF TRAFFIC DATA

a) INDOT staff responsible for data analysis and processing (as on 15 December 1997)

JOB TITLE	DUTIES
Traffic Data Analyst (1 each)	• Annualization of 48-hour counts using seasonal adjustment factors • Assists in maintaining WIM, Telemetry and Coverage Count Programs • Generation of new AADTs and historical data • Prepare Interstate Traffic Flow Map • Data verification and analysis of break-even points in traffic for preparation of County Flow Maps
Data Analysis Specialist for Weigh-in-motion data. (1 each)	• Validation of collected field data • Checking field data for possible errors and correction of erroneous data • Preparation of daily and monthly error reports • Forwarding of daily error reports to field staff for diagnosis and repair of malfunctioning equipment • Preparation of monthly WIM summaries • Export of traffic volume aspect of WIM data to Telemetry Data Analysis Specialist • Preparation of monthly TMG reports • Saving of all data and reports on optical disk
Data Analysis Specialist For Telemetry data. (1 each)	• Consolidation of data • Analysis of ADT's • Checking of field data for possible errors and correction of erroneous data • Receipt and consolidation of traffic volume data from imported WIM data • Preparation of monthly volume reports for FHWA • Preparation of ADT/volume report for MPO's • Preparation of annual report showing adjustment factors, design hour volumes and ADT's
Data Analysis Specialist For Coverage Count data. (1 each)	• Review and compilation of checksheets and validation of Coverage Count data • Evaluation and application of excess axle adjustment and computation of percentage of commercial vehicles • Generation of data in appropriate format for use in mainframe
Traffic Forecasting Specialist (1 each)	• Develop procedures for forecasting rural and urban traffic patterns • Prepare and provide Traffic Projection Reports as requested • Maintain 20-year ADT history file

APPENDIX 4 (cont'd)

EXISTING PERSONNEL FOR ANALYSIS AND PROCESSING OF TRAFFIC DATA

b) MPO staff responsible for data analysis and processing (as on 15 December 1997)

METROPOLITAN PLANNING ORGANIZATION (MPO)	TRAFFIC DATA ANALYSIS STAFF (AS ON OCTOBER 15, 1997)
1. The Indianapolis Metropolitan Planning Organization	1 Traffic Data Analyst
2. The Madison County Council of Governments (MCCOG)	2 Transportation Planners carry out data collection, data analysis and report preparation
3. City of Bloomington Planning Department	2 staff responsible for data analysis as well as supervision of data collection activities
4. Kentuckiana Regional Planning and Development Agency (KIPDA)	3 staff responsible for data analysis as well as data collection and equipment maintenance
5. The Area Plan Commission of Tippecanoe County (APC)	1 Traffic Data Analyst
6. Michiana Area Council of Governments (MACOG)	3 office staff responsible for data analysis and processing
7. Kokomo-Howard County Government Coordinating Council (GCC)	1 Traffic Data Analyst
8. Northwestern Indiana Regional Planning Commission (NIRPC)	2 Traffic Data Analysts
9. Muncie Area Planning Commission	2 office staff responsible for data analysis and processing
10. Northern Indiana Regional Coordinating Council (NIRCC)	An Associate Planner and 1 of the data collection technicians are responsible for data processing and analysis
11. West Central Indiana Economic Development District (WCIEDD)	2 staff carry out both data collection and data analysis

TOTAL STAFF FOR DATA ANALYSIS AND PROCESSING IN ALL MPOS = **21**

This list excludes data analysis staff of the MPO responsible for the Evansville area.

APPENDIX 5
TRAFFIC DATA COLLECTION ACTIVITIES BY METROPOLITAN PLANNING ORGANIZATIONS (MPOS) IN THE STATE OF INDIANA

The role of the Metropolitan Planning Organizations in traffic data collection has increased significantly since 1993 due to increased responsibilities placed on them by air-quality and surface transportation legislation. Traffic monitoring activities for both HPMS and non-HPMS road sections on state roads in urban areas are the responsibility of INDOT. However, the MPOs are responsible for counts on HPMS and non-HPMS sections on non-state roads and streets in urbanized areas within their jurisdiction. Traffic data collected by the MPOs are used by such organizations for their planning purposes and are also forwarded to INDOT for publication in various reports submitted to the FHWA. Particular emphasis is placed on urbanized areas that have been designated as NAAQS areas, i.e., areas where national air-quality standards are not being attained) by the Environmental Protection Agency (EPA). The Clean Air Act Amendments 1990 (CAAA) requires that states/MPOs having such affected areas should estimate total annual vehicular travel using the HPMS. Besides HPMS data, other traffic data that the MPOs collect for their planing purposes and also for reporting to INDOT includes the following:

- Volume counts and classification data of use to the management systems
- Vehicle occupancy data
- Data on the operations of high-occupancy vehicles (HOVs)
- Highway surveillance systems inventory data

There are currently 13 MPOs in the State of Indiana. This information was obtained through various means of correspondence with the planning staff in these organizations. To date, the only MPO that has failed to respond to requests for such information is that responsible for the Evansville area.

MPOs should be encouraged to use a uniform reporting format when submitting their traffic data to INDOT. A sample form for such reports is provided as Appendix 8 of the main report. Also, MPOs should be encouraged to submit maps of their areas of jurisdiction, indicating count locations, count types, dates of counts, etc. At least two MPOs have begun processing their traffic data using electronic maps. Other MPOs should be encouraged to follow this example. Furthermore, the MPOs should submit documentation on the methods used in the development of adjustment factors, and how they apply these factors.

Below are brief descriptions of the traffic data collection activities carried out by some of these MPOs.

1. *Department of Metropolitan Development, City of Indianapolis*

With the aid of a consultant, the Indianapolis MPO has established a Transportation Monitoring System which provides a comprehensive compilation, using GIS, of

available transportation and traffic data for the region. Within the 1989-1994 period, the Indianapolis MPO, through its various county divisions, carried out a total of 258 volume counts on non-state roads in its jurisdiction (ref. *Indianapolis Transportation Monitoring System: The MPO Count Program*, published on 24th July, 1997 by HNTB Corporation). The duration of counts ranges from 48 to 72 hours. 1 percent of all counts are for vehicle classification. The number of HPMS counts carried out by the MPO was not indicated in the report. Retention of data is done on a computer hard drive, with backups on floppy disk and hard copy printouts. The Indianapolis MPO has 68 counters in its inventory, consisting of models of various makes and models such as Peek GK-5000 and Numetrics NC-90s. 2 Zenith 486 computers are used for data analysis and processing, while software includes Histar, TAS, TMCPRO, VOLPRO, and IMC. 2 technicians carry out data collection, while 1 data analyst is responsible for processing and analysis of data.

2. *The Madison County Council of Governments* (MCCOG)
The MCCOG traffic count program consists of cordon counts, screenline counts, coverage counts and HPMS counts. 48-hour vehicle counts are taken at 105 HPMS sections within the MCCOG area, with approximately one-third being carried out each year. MCCOG carries out axle corrections and seasonal adjustments based on the averages derived from INDOT's permanent ATR counters. Roads of all functional classes, with the exception of Interstates, are counted. Classification counts, which make up about 10% of all counts, are only carried out upon special request. MCCOG has formally documented its data collection procedures in a booklet titled The Integrated Traffic Volume Counting Procedure Manual, published in September, 1982 by MCCOG. Results of the annual count program are stored using TransCAD software, and the maps are available in AutoCAD and TransCAD.
MACOG has 2 transportation planners responsible for data collection, analysis and report preparation. Equipment used for vehicle volume count program, which was acquired in 1992, consists of four Archer 6400 series manufactured by Golden River. This equipment is also capable of collecting vehicle classification and speed data. Hardware used for data analysis consist of 2 Gateway Pentium computers, while Archanal/Stratgraf Version 4.1, PC Plus software, TransCAD and dBase 4.5 are used for data analysis and processing.

3. City of Bloomington Planning Department
The Planning Department of the City of Bloomington carries out 178 traffic volume counts on non-state road sections in its area. Of this 78 are HPMS sections, while the rest are for coverage count purposes. The city also carries out an unspecified number of counts for traffic calming studies and turning movement assessments. The counts generally last for 48 hours and are done for each direction of travel. Counts are made to cover all road functional classes and have a 3-year cycle length.
Two staff is responsible for data analysis and supervision of data collection activities. Three other staff, assigned to this department in an agreement with the City Engineering and County Highway Departments, carry out collection of traffic data for the planning department.

This MPO has the following equipment in its inventory: 6 TRAX II Classifiers (TAS Plus Software); 3 NC 90 Classifier/counters, and 5 NC 40 Classifier/counters that use HISTAR LP Version 5.4 software); and 1 Jamar IMC IV that uses PETRA turning movement software. About 12 twelve such tube counters are needed to fulfill the equipment needs of this MPO. Four 486 MZ computers, that use Hi-Star 6.0, are available for processing of the traffic data.

4. Kentuckiana Regional Planning and Development Agency (KIPDA)
Over the period 1991-1995, KIPDA carried out 4217 traffic volume counts at 3407 non-state road sections, while about 400 counts were carried out by INDOT at state road sections within this area. The number of HPMS sections that form part of this sample size has not been indicated by the MPO. KIPDA makes efforts to count locations having significant traffic volumes every 3 years, while traffic generator locations in general are counted at 5-year intervals. Roads of all functional classes, with the exception of Locals, are counted. However, Locals are counted if there is a specific request for counts at those locations. Since 1994, 1005 of all volume counts include vehicle classification. Because the type of equipment used i.e., NC-90A, is capable of collecting both data types. KIPDA retains count results in Excel spreadsheet format and stores such data in hard drives and on floppy disks. Also, KIPDA publishes its traffic data biannually.
Currently, KIPDA has 3 staff responsible for data collection, analysis and equipment maintenance. Short-term counts largely consist of determination of turning volumes using manual methods with the aid of a Jamar DB-100 count board. Other equipment includes 4 MITRON counters, 4 Numetrics magnetic imaging counters (NC 90-A), and 2 Numetrics magnetic imaging counters (NC 40-A). KIPDA is generally satisfied with the performance of this equipment, but have expressed a desire for additional equipment to replace old tube counters in future and to serve as back-ups to cover downtime periods of the present equipment. Other equipment includes 4 count boards, 1 Jamar DB100, and 1 Peek GK-5000.
1 IBM compatible microcomputer (486 DX, 100MZ, 1.2GB) is used to manipulate raw traffic data using standard software such as Excel spreadsheet, Access database, AND Windows 3.1. KIPDA also has a laptop computer that uses PETRA LT and HISTAR software to download data from field equipment. According to KIPDA, both hardware and software are generally adequate for their present needs.

5. *The Area Plan Commission of Tippecanoe County (APC)*
A total of 245 volume counts were carried out for this MPO on non-state roads and streets between the 1994 and 1996-count period. However, this MPO did not specify what fraction of this number were HPMS counts. Currently, there is no specific cycle length set for APC's counts, even though the present cycle length ranges from 3-4 years. APC develops and applied INDOT-approved seasonal adjustment factors. Roads of all functional classes are counted, with emphasis given to Principal and Minor Arterials. Classification counts are done only on special request. Data is stored in three ways: in the hard drive for quick retrieval and use, on backup floppy diskettes, and on hard copies for filing.

Currently, only 1 full-time staff is responsible for analysis of traffic data, but the number of staff for data collection has not been indicated by this MPO, because this activity is carried out by the individual cities and the county. The Commission has 12 StreeterAmet TrafiComp III counters. APC has two computers with the following features: Gateway model 486 DX, 33MZ and 8MB RAM, are available for analysis, processing and storage of traffic data. This equipment are scheduled to be upgraded with Pentium 100 MZ and 16 MB RAM. Traffic counts data are retained on a hard drive in a spreadsheet format. All three jurisdictions within this MPO each have a 486 computer.

6. *Michiana Area Council of Governments (MACOG)*
MACOG maintains a 3-year cycle for its counts, which are carried out to cover roads of all functional classes. Seasonal adjustment factors, developed using 1995 data from INDOT's permanent count stations, are applied to count results. About 5% of all counts are for vehicle classification. Data from traffic counts are retained in a database format on computer hard drives. MACOG also prints a traffic count book every year. Currently, there are 58 counters in MACOG's data collection equipment inventory. The dominant models are Numetrics Histars NC90a (32) and Peek GK-500 (14), while there are 8 Peek GK-4000 and 4 GK-6000. Two computers (one 486 desktop and one 386 laptop) are used for data analysis. TAS Plus software is used to analyze data generated by the GK counters, while Numetrics counters use Histar software. MACOG has 1 data collection technician, and 3 office staff for data processing and analysis.

7. *Kokomo-Howard County Government Coordinating Council (GCC)*
Coverage counts by this MPO are carried out on a three-year cycle for a sample that includes roads of all functional classes. A total of 239 counts are carried out. O these, 8 are classification counts. GCC has 4 counters of the Peek GK-5000 series, while the city and county have 4 counters each of the GK-5000 and Mitron 3000 types respectively. GCC has 1 IBM 386 computer for data processing and analysis. This MPO has 1 office staff responsible for data analysis, but has no data collection personnel as that activity is carried out by for GCC by the city and county under an agreement.

8. *Northwestern Indiana Regional Planning Commission (NIRPC)*
NIRPC carries out counts on a three-year cycle on all roads that are not on the state system. Currently, efforts are in progress by NIRPC to develop seasonal and axle adjustment factors. Approximately 20% of all counts are for vehicle classification. NIRPC stores its data in spreadsheet format. There are currently 12 counters in the equipment inventory. Two 386 PCs are used with Paradox and Quattro Pro software for data analysis and processing, while only one 1 technician is used for data collection during summer.

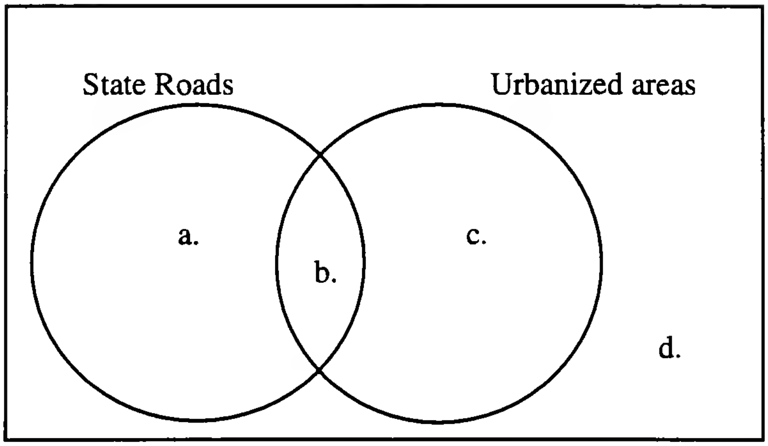
9. *Delaware-Muncie Metropolitan Planning Commission*
A duration of 48 hours during weekdays is used for coverage count activities by this MPO. Seasonal adjustment factors are developed using data from INDOT's ATR

stations, and are applied to coverage count results. Data collection activities are primarily carried out for principal arterials, minor arterials, and collectors. About 1% of all counts is for vehicle classification. Data such as hourly Hourly counts, ADTs, and Peak Hourly Volumes are stored in a Paradox database. There are 5 counters in the equipment inventory: 4 ADR-100s and I Peek 241 counters. Two Sun computers and 3 microcomputers (Dell, Ambra and Swan) are used with Paradox, Visa, and Q&A software for data analysis and processing. Three technicians are involved in data collection, out of which 2 also carry out data analysis and processing.

10. *Northern Indiana Regional Coordinating Council (NIRCC)*
NIRCC states that a 3-year cycle length is the objective. This implies that this target is currently not being met. Axle and seasonal adjustment factors are developed by NIRCC and applied to its counts. Roads of all classes are covered. Data is stored in Lotus format, with backup hard copies on file. NIRCC has 22 Peek 241 TrafiComp counters and 8 Model 101B counters. There are 2 computers for data analysis and processing A 486 IBM-compatible PC and a 486 IBM notebook. Currently, there are 2 data collection technicians, 1 full-time and 1 part-time. Also, an associate planner oversees the counting program. The associate planner and full-time technician are responsible for analysis and processing of collected data.

11. *West Central Indiana Economic Development District (WCIEDD)*
Roads of all functional classes are covered in this MPO's coverage count program. A 3-year cycle length is used. Data is stored/maintained as text files and Paradox files, and also using Lotus for Windows, on hard drives and floppy disks. Hard copy printouts are also stored on file. WCIEDD currently has 6 counters of the Tally Traffic 501 model in its inventory. Two PCs (1 Packard Bell Pentium 60, and 1 IBM-compatible 486-33) are used for data analysis and processing. Software used includes Paradox, Lotus for Windows, Harvard Graphics, and Forecast Pro. A staff strength of 2 personnel is used to carry out both data collection and data analysis. The WCIEDD is currently engaged in an update of its formal manual for procedures for data collection and analysis that would make it compatible with the February 1995 edition of the *Traffic Monitoring Guide*.

Data collection and analysis procedures of the MPOs generally conform to INDOT methods. This may be attributed to the regular workshops organized by INDOT for this purpose. It is recommended that such workshops be continued. One area, however, which appears to be lacking is that periodic equipment performance and calibration checks are not currently being carried out. This is obviously due to the low staffing strengths of most MPOs. Whenever possible, INDOT field staff may assist MPOs in carrying out this activity.
The relationship between data collection activities by INDOT and by the MPOs may be appropriately illustrated as shown in the figure below:



a. State roads in non-urbanized areas- data collection by INDOT
b. State roads in urbanized areas- data collection by INDOT
c. Non-state roads in urbanized areas (e.g., local roads, city and county roads) - data collection by MPOs
d. Non-state roads in non-urbanized areas- data collection by INDOT

APPENDIX 6

TRAFFIC MONITORING SYSTEMS -- THE EXPERIENCE OF OTHER STATES

1. *Florida*

Florida DOT has designed and implemented a traffic monitoring system for the 12,000 miles of federal aid eligible state highways. In all, Florida has about 113,000 miles of roads, out of which approximately 12,000 miles are on the State system. The state has a large permanent traffic volume, vehicle classification, and WIM monitoring program consisting of about 250 permanent counters (many of which are capable of classification) and 17 permanent WIM sites. Currently, a major objective of Florida DOT's ATR program is to install in each county, one ATR in for each highway functional class for which there is a minimum of 10 miles in that county. The HPMS mandates a coverage count program of about 2,000 sample sections. Florida DOT includes these locations among a total of approximately 6000 sites. To satisfy ISTEA requirements, Florida DOT has adopted a procedure to ensure that at least one vehicle classification survey will be taken on each segment of the National Highway System. Vehicle classification is also vigorously pursued under the general coverage count program. Florida DOT districts have gone mostly from simple volume counts to portable vehicle classification surveys.

2. *Kansas*

Kansas has implemented a traffic monitoring program for traffic volume, vehicle classification and truck weights based on the procedures suggested in FHWA's Traffic Monitoring Guide. The State currently meets current traffic data needs for these three count types. However, due to new requirements, the locations of permanent sites are being re-evaluated. An outreach program is underway to coordinate the traffic data programs of cities and counties to facilitate the exchange of traffic data. The ORACLE database system is being used to implement a coordinated data processing operation to manage and utilize all the available data from all sources. The data processing will also be interfaced with a geographic information system (GIS).

3. *Minnesota*

Minnesota DOT has 120 ATRs located on routes of various classes ranging from county road and municipal streets up through the Interstate system. Ward's method of clustering was used to establish groups for the ATRs. Data is managed using Traffic Analysis Expert System software, which was developed by a consultant retained by the FHWA in cooperation with Minnesota, Kansas, and Colorado. Software routines using Statistical Analysis Systems (SAS) have also been developed to input and output the data from the Expert System. Short-term equipment is regularly tested for accuracy. Minnesota DOT places much emphasis on the expertise and skill of traffic data collectors, in a bid to ensure accurate results and to reduce the need for recounts. The State is sponsoring a pooled-fund study to develop data editing procedures and software to increase the efficiency of traffic data processing and to ensure that the quality of traffic data is maintained.

4. *Missouri*

The implementation of Missouri's traffic data program followed the guidelines of FHWA's Traffic Monitoring Guide. The program currently consists of about 108 Telemetry ATRs that take volume counts, 5,000 annual coverage counts, 4000 annual special volume counts, 300 portable classification counts over a three year cycle, and collection of WIM data using permanent and portable equipment at several sites.

5. *Maryland*

Maryland's traffic monitoring program consists of 70 ATR stations (which includes 2 permanent WIM stations), 2450 coverage stations, which include 350 classification stations, and approximately 1400 ramp counts to cover the Interstate system. The coverage, classification and ramp counts are done on a three-year cycle. Also, Maryland DOT carries out 650 portable and 400 manual counts on special request.

6. *Idaho*

Idaho DOT has about 150 ATR devices for permanent volume counts. These are Diamond scale devices, and models include Phoenix, 2001, and Unicorn. Also, there are 13 ECM Hestia devices used for vehicle weight and classification. Idaho DOT groups ATR stations on the basis of traffic patterns at the sites, and not on highway classification. 2600 short-term volume and classification counts were carried out in 1996. Most ATR and short-term counts are processed through the TRADAS software on a Unix system. WIM data is presently processed separately on a PC, using SAS programs developed in-house. Idaho attaches much importance to the accuracy of data collection equipment, and comprehensive checks are regularly carried out to ensure that accurate and reliable data is obtained. Data from the continuous counts are collected, processed, analyzed, and reported in accordance with FHWA's Traffic Monitoring Guide. Vehicle classification activities on the National Highway System are sufficient to assure that every major segment is covered on a cycle not greater than three years.

7. *New York*

The DOT of the State of New York has about 83 continuous count sites at various locations in the state. These sites are equipped with PEEK ATRs and are accessed by modem from the main office in Albany. Vehicle weight data is collected for pavement research purposes at 12 weigh-in-motion sites. New York DOT plans to upgrade all continuous counters to enable them collect vehicle classification, and also to upgrade some of this equipment to collect truck weight data. Data analysis is carried out on an IBM mainframe computer, using, primarily, COBOL and SAS jobs. Diamond counters are used to carry out about 6,000 coverage counts every year using 48-hour (minimum) count duration. Vehicle classification data is collected on a short-term basis with about 300 samples collected per year. Efforts are underway to collect vehicle classification data at all NHS segments. However, one limitation is the inability for currently available portable traffic count technology to collect acceptable classification data on multi-lane or high volume facilities, which are characteristic of many NHS segments. The traffic monitoring staff in the main office consists of about 12 people. 15 years of

data at the aggregate level is retained in an active file on a mainframe computer. Detailed short-term counts and aggregate data older than 15 years are retained on back-up devices. There are currently no plans to delete any data. New York DOT has documented its procedures for data collection, analysis and field testing of data collection equipment.

APPENDIX 7

SOME EXISTING REPORTS AND PUBLICATIONS BY INDOT TRAFFIC STATISTICS UNIT FOR USE BY VARIOUS STATE AND FEDERAL AGENCIES AND THE PRIVATE SECTOR

Report/Publication
County Flow Map Book
Telemetry Station Report
Weigh-in-Motion (WIM) Report
Weigh-in-Motion (WIM) Error Report
HPMS Report
Bridge Counts Report
FHWA Vehicle Classification Report
LTPP Truck Weight Report

Frequency of reporting varies. Some reports or sections therein, are submitted only in response to requests by the end users. Others, such as the Telemetry Report, are submitted on a periodic basis.

End-users include various federal, state, local and private sector agencies, such as FHWA, INDOT Planning Division, Metropolitan Planning Organizations, and private developers.

APPENDIX 8
RECOMMENDED FORMAT FOR ANNUAL REPORTING OF TRAFFIC DATA BY MPOS

Count #	Count Type	Road name & exact count location	Road Functional class	Year of count	HPMS status	HPMS # (if HPMS)	Count status (regular/ special)	Count Results	Remarks
1	*traffic volume*	*SR-25, 0.5 miles north of SR-24*	*Urban Minor Collector*	*1995*	*HPMS*	*101101282721*	*Regular*	*24, 373*	

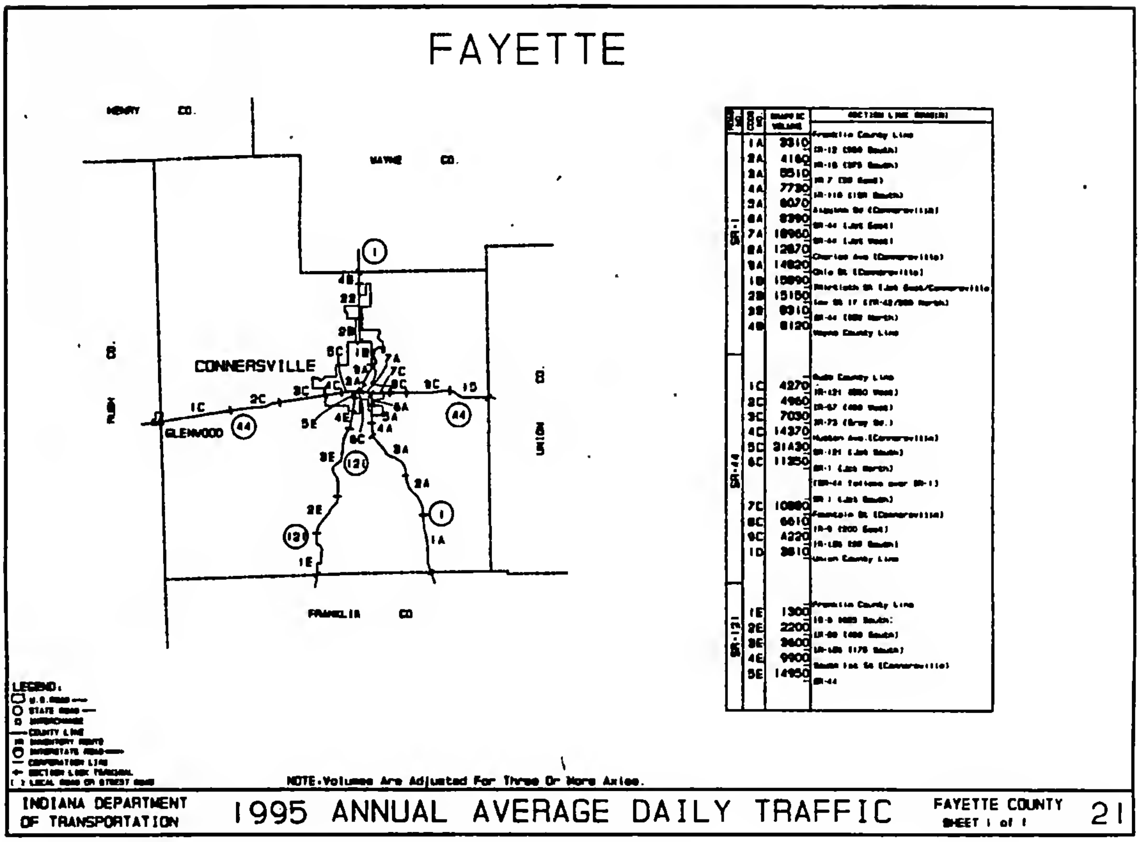
A detailed map showing locations of counts should accompany submission of this form.

APPENDIX 9
EXAMPLES OF END-USER'S TRAFFIC DATA NEEDS

Highway Management Phase	Traffic Volumes	Vehicle Classification	Truck Weights
Engineering Design	Capacity analysis Geometric design	Pavement design	Structural design of pavements and bridges
Engineering Economy	Benefit of highway improvements	Estimation of vehicle operation costs	Benefit of truck climbing lanes
Finance	Estimates of road revenue	Highway cost allocation	Weight-distance tax allocation
Legislation	Selection of state highway routes Air quality assessment	Policy-making for speed limits and oversize vehicles	Vehicle weight enforcement
Planning	Location and design of highway systems	Forecasts of travel by vehicle type	Resurfacing forecasts
Safety	Design of traffic control systems Accident analysis	Safety conflicts due to vehicle mix Accident rates per vehicle class	Posting of bridge load limits
Statistics	Estimation of average daily traffic	Travel by vehicle type	Estimation of weight-distance traveled
Private Sector	Location of service areas	Marketing keyed to particular vehicle types	Trends in freight movement

Sources: Traffic Monitoring Guide (1994), AASHTO Guidelines for Traffic Data Programs, and "A Statistical Approach to Statewide Traffic Counting", by Stephen G. Ritchie

APPENDIX 10
Sample of County Flow Map



APPENDIX 11: Sample of ATR Site Information Sheet

5732

2120 **ON I-74 0.60 MI. E. OF SR 63** 2120 WIM 5130

COVINGTON
City

VERMILLION
County

Location and Site Characteristics

ON I-74 10.59 MI W OF US 41
ON I-74 1.79 MI W OF FOUNTAIN / VERMILLION C/L
ON I-74 3.15 MI W OF COVINGTON EXIT #8

074-I
Road number — Address — Township

083 -VERMILLION — County
165 — Feds Co. #

CRAWFORDSVILLE — District
616 VEEDERSBURG — Sub-District

0 — Lanes
EB — Dir. Lane #1
3-Rural Interstate — Functional Class

4+83 — Mile marker
65 — Speed Limit
ASPHALT — Pavement Surface

000074000000 — HPMS Segment
Speed site
SHRP Site

Functional Class

1. urban interstate
2. urban arterial
3. rural interstate
4. rural arterial
5. rural collector/locals

Phone Number

1 — Polling group

1200 — Baud rate

22 — Seq. #

Notes

Telephone Company

Account Number — Vendor Code — Office Phone

address

city

Electric Company

Account Number — Vendor Code — Office Phone

address

city

APPENDIX 12: Sample of Output Data from ATR Stations
(Class by Gross Vehicle Weight Report)

Class by Gross Vehicle Weight Report

Site: 1465-INDT-W-546 Lanes: #1 #2 #3 #4 #5 #6
Classification: FHWA Start Class 0 End Class 23
FROM: Wed Feb 01 00:00:00 1995 TO: Wed Mar 01 00:00:00 1995

	Number of Vehicles														
	Classification														
kips	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
0->5	897	17127	2619	1109	0	246	60	0	0	0	0	0	0	0	22058
5->10	6657	235	1527	32300	30	16948	527	5	26	58	0	0	0	0	58313
10->15	3522	1	14	2562	253	5734	1521	138	422	1066	12	0	0	0	15245
15->20	2298	0	2	244	1324	2869	2232	103	861	2063	22	0	0	0	12018
20->25	1491	0	0	78	985	1107	857	92	1196	3863	80	3	0	0	9752
25->30	1770	0	0	49	477	524	507	83	1229	7067	219	42	1	0	11968
30->35	2039	0	0	28	230	263	346	87	1005	9632	337	102	8	0	14077
35->40	1935	0	0	11	119	102	222	66	684	7656	276	146	24	0	11241
40->45	1812	0	0	16	67	71	140	82	423	6833	238	201	28	0	9911
45->50	1630	0	0	5	45	49	78	81	243	6363	213	329	59	1	9096
50->55	1497	0	0	11	18	28	46	199	138	6711	238	391	63	2	9342
55->60	1321	0	0	1	11	10	28	465	87	6946	220	471	67	1	9628
60->65	1458	0	0	1	6	6	18	532	57	7321	237	461	58	3	10158
65->70	1801	0	0	0	6	2	9	458	28	8241	331	389	65	0	11330
70->75	1979	0	0	0	1	0	7	309	19	7590	426	219	43	0	10593
75->80	895	0	0	0	0	0	4	89	9	3482	253	123	23	0	4878
80->85	273	0	0	0	0	0	1	24	3	1001	66	45	8	4	1425
85->90	113	0	0	0	0	0	1	9	1	326	24	7	3	1	485
90->95	61	0	0	0	0	0	0	7	3	102	16	5	2	3	199
95 +	134	0	0	0	0	0	2	18	6	139	24	8	3	11	345
Total	33583	17363	4162	36415	3572	27959	6606	2847	6440	86460	3232	2942	455	26	232062

Vehicle records used in this report include:
Good vehicles

Total Counts As Defined By Report Parameters:

Error	Warning	Stored
464338(24.0%)	5939(0.3%)	707206(36.5%)

APPENDIX 13: Sample Page of Vehicle Classification Coverage Count Report

1995 PERCENT COMMERCIAL VEHICLES

YEAR: 1995
County Name: KOSCIUSKO
County Number: 43
Group Code: A

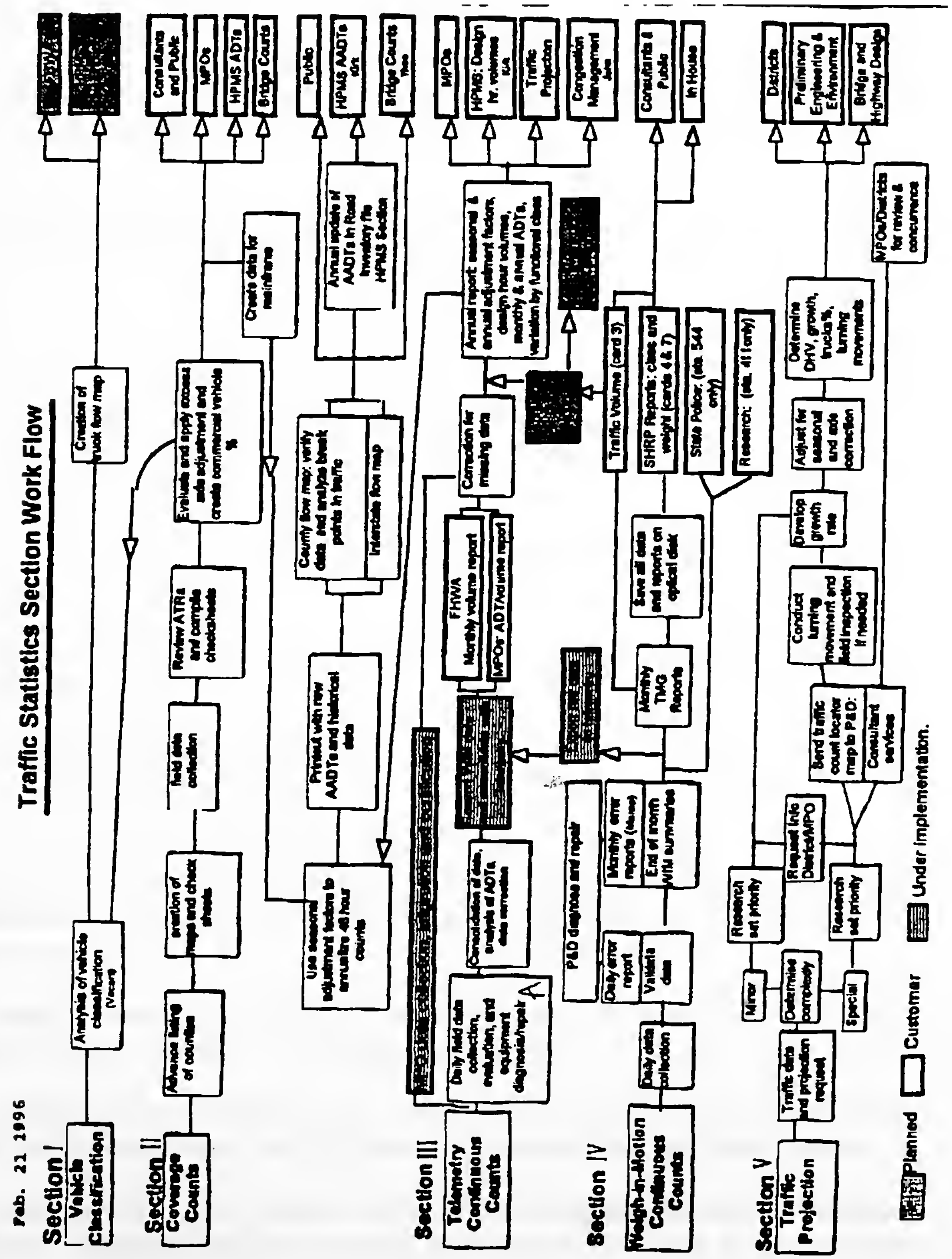
STA	Route	LOCATION2	CARS	COMM VEHICLES	% C. V.
0010	US 30	ON US 30 0.10 MI E OF MARSHALL CO LI	7938	4825	37.8%
0020	US 30	ON US 30 0.10 MI E OF SR 19	8515	4810	36.1%
0030	US 30	ON US 30 0.20 MI W OF SR 15	11238	4844	30.1%
0041	US 30	ON US 30 0.10 MI OF IR 226 (200N)	13876	5286	27.6%
0050	US 30	ON US 30 0.10 MI WEST OF SR 13	12562	4624	26.9%
0070	US 30	ON US 30 0.10 MI W OF WHITLEY CO LIN	11972	5549	31.7%
0080	SR 10	ON SR 10 0.10 MI WEST OF SR 19	942	47	4.8%
0100	SR 13	ON SR 13 0.10 MI N OF WABASH CO LINE	3014	280	8.5%
0130	SR 13	ON SR 13 0.10 MI NORTH OF SR 14	2575	328	11.3%
0150	SR 13	ON SR 13 0.10 MI NORTH OF US 30	4797	574	10.7%
0170	SR 13	ON SR 13 0.10 MI S OF ELKHART CO LIN	5955	575	8.8%
0190	SR 14	ON SR 14 0.10 MI EAST OF FULTON CO L	1122	83	6.9%
0220	SR 14	ON SR 14 0.10 MI WEST OF SR 13	631	92	12.7%
0230	SR 14	ON SR 14 0.10 MI EAST OF SR 13	1592	139	8.0%
0240	SR 14	ON SR 14 0.10 MI W OF WHITLEY CO LIN	1828	191	9.4%
0260	SR 15	ON SR 15 0.10 MI N OF WABASH CO LINE	3557	563	13.7%
0282	SR 15	ON SR 15 8 MI N OF SR 14	5884	586	9.1%
0331	SR 15	ON SR 15 2 MI N OF US 30	9917	1585	13.8%
0340	SR 15	ON SR 15 0.10 MI S OF ELKHART CO LN	7351	1182	13.9%
0360	SR 19	ON SR 19 0.10 MI N OF FULTON CO LINE	1446	157	9.8%
0390	SR 19	ON SR 19 0.10 MI S OF SR 10	1413	203	12.6%
0400	SR 19	ON SR 19 0.10 MI N OF SR 10	1855	261	12.3%
0421	SR 19	ON SR 19 1.12 MI N OF US 30	831	93	10.1%
0430	SR 19	ON SR 19 100'S OF ELKHART CO LINE	4621	382	7.6%
0450	SR 25	ON SR 25 0.10 MI E OF MARSHALL CO LI	2645	263	9.0%
0471	SR 25	ON SR 25 0.10 MI E OF IR 9	3883	227	5.5%

APPENDIX 14: Sample Page of Traffic Volume Coverage Count Report

ELKHART COUNTY COVERAGE COUNT PROGRAM PRINTOUT DATE: 04-Sep-97

STA	Route	Check Sheet Description	YEAR	FLD MAN	D R	R U	F C	F A	M M	D D	N/E LANE 1	N/E LANE 2	S/W LANE 1	S/W LANE 2	24 HR AVG	AXLE ADJ.	AXLE ADJ. VOL.
0010	I-80/90	INTERCHANGE #1 RAMP C	1996	KS	S	2	1	7	06	12	4500	0	0	0	4500	1.000	4500
0020	I-80/90	INTERCHANGE #1 RAMP D	1996	KS	S	2	1	7	06	12	4671	0	0	0	4671	1.000	4671
0030	I-80/90	INTERCHANGE #2 RAMP C	1996	RT	S	0	1	7	06	25	0	0	1962	0	1962	1.000	1962
0040	I-80/90	INTERCHANGE #2 RAMP D	1996	RT	S	0	1	7	06	25	2327	0	0	0	2327	1.000	2327
0050	I-80/90	INTERCHANGE #2 RAMP A	1996	RT	S	0	1	7	06	25	2942	0	0	0	2942	1.000	2942
0060	I-80/90	INTERCHANGE #2 RAMP D	1996	RT	S	0	1	7	06	25	0	0	2619	0	2619	1.000	2619
0080	US 6	CO KEY A-2	1996	KS	C	0	3	3	07	31	4047	0	3898	0	7945	1.000	7945
0081	US 6	NAPPANEE NAP	1996	KS	A	1	3	8	07	31	8148	0	7099	0	15247	0.805	12274
0082	US 6	NAPPANEE NAP	1996	KS	A	1	3	8	07	31	7509	0	7834	0	15343	0.805	12351
0090	US 6	NAPPANEE NAP	1996	KS	A	1	3	8	07	31	7471	0	7873	0	15344	0.805	12352
0100	US 6	NAPPANEE NAP	1996	KS	A	1	3	8	08	06	9062	0	9531	0	18593	0.805	14967
0101	US 6	NAPPANEE NAP	1996	KS	A	1	3	8	08	01	8047	0	8389	0	16436	0.805	13231
0102	US 6	NAPPANEE NAP	1996	KS	A	1	3	8	08	01	5740	0	6004	0	11744	0.805	9454
0103	US 6	NAPPANEE NAP	1996	KS	A	0	3	3	08	01	4879	0	4977	0	9856	0.805	7934
0110	US 6	S.R. #16	1996	KS	C	0	3	3	07	25	3757	0	3950	0	7707	1.000	7707
0120	US 6	S.R. #16	1996	KS	A	0	3	3	07	30	4786	0	4848	0	9634	0.805	7755
0121	US 6	S.R. #16	1996	KS	A	0	3	3	07	30	4629	0	4623	0	9252	0.805	7448
0122	US 6	S.R. #16	1996	KS	A	0	3	3	07	17	4659	0	4499	0	9158	0.805	7372
0130	US 6	CO KEY I-2	1996	KS	C	0	3	3	07	17	3216	0	3039	0	6255	1.000	6255
0140	US 6	CO KEY I-2	1996	KS	C	0	3	3	07	16	3727	0	3660	0	7387	1.000	7387
0150	US 6	CO KEY J-2	1996	KS	A	0	3	3	07	16	4898	0	4731	0	9629	0.803	7732
0160	US 6	CO KEY J-2 WPMS	1996	KS	A	0	2	2	07	16	4987	0	4876	0	9863	0.803	7920
0170	US 6	CO KEY K-2 WPMS	1996	KS	C	0	2	2	07	16	4545	0	4203	0	8748	1.000	8748
0190	US 20	INTERCHANGE #4 MAINLINE	1996	JW	C	2	2	2	08	06	9579	2159	9390	3088	24215	1.000	24215
0191	US 20	INTERCHANGE #4 RAMP A	1996	JW	S	2	2	2	08	06	2248	0	0	0	2248	1.000	2248
0192	US 20	INTERCHANGE #4 RAMP B	1996	JW	S	2	2	2	08	06	4190	0	0	0	4190	1.000	4190
0193	US 20	INTERCHANGE #4 RAMP C	1996	JW	S	2	2	2	08	06	3720	0	0	0	3720	1.000	3720

APPENDIX 15: INDOT Traffic Statistics Section WorkFlow



APPENDIX 16

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